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Transactions of American Society for Steel Treating

Vol. V January, 1924 No. 1

SPECIAL FEATURES

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Weldless Rings for Gears forged from Agathon Alloy Steel by The Mitchell Steel Company, Cincinnati, Ohio

Below: Drawing down a weldless ring in Mitchell Steel Company plant

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AGATHON ALLOY STEELS

TRANSACTIONS
of the
American Society for Steel Treating

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PROGRESS OF INDUSTRIAL STANDARDIZATION DURING 1923[1]

DURING the past year, industrial standardization has continued to develop as one of the most active and important phases of American industry. Progress has been made in the standardization of raw materials, manufacturing processes and finished products. This is equally true whether looked at from the point of view of the factory, of the industrial or technical association, or of a national movement.

A striking development is the increased systematic use of specifications in public purchases, notably in the federal and in several of the state governments. The National Association of Purchasing Agents and the National Council of Governmental Purchasing Agents are devoting much time and attention to the subject. At the direction of Mr. Hoover, the department of commerce is preparing to publish a "Dictionary of Specifications for Public Purchases," which will make easily available information as to what specifications are in existence, to what classes of use they apply, and how they may be obtained.

The Federal Specifications board has completed the second year of its activity. In this, the American Engineering Standards committee has co-operated by obtaining criticisms from the various interested industries of proposed specifications of the federal government before the specifications are finally adopted by the board. To date, the board has adopted approximately ninety specifications, and the committee has

1. By A. W. Whitney, chairman American Engineering Standards Committee.

secured criticism of industry on about the same number. From these systematic efforts to bring governmental purchases in line with the best commercial practice, important economies both to industry and government are resulting.

The Division of Simplified Practice of the Department of Commerce continues to exert a most stimulating influence on the standardization movement, particularly in emphasizing the efficiency results of standardization to the business man.

Through the organization of the American Marine Standards committee, work has been initiated in this important industry. Very little in this field has heretofore been done in this country, although very considerable activity has been going on for some time in Germany and Great Britain.

The most striking aspect of the movement for industrial standardization is the development of standardization on a national scale. More than 150 undertakings now have official status before the American Engineering Standards committee, the national clearing house for standardization. Fifty standards have received final approval by the committee, twenty-two of which were approved during 1923. The importance of the broadly democratic methods followed in this clearing house work is receiving increasingly widespread recognition. In it all parties concerned with any standard, producers, consumers, and representatives of the public and government, participate (1) in deciding whether the work should be undertaken at all, (2) in formulating the standard, and (3) in its ultimate approval. Thus the industries are developing and using such standards as best fit their needs, without danger of such technical industrial matters becoming subject to legal enforcement or to governmental pressure. Is it not probable that many other of our important industrial problems will find their solutions by closely analogous methods?

In July, the second conference of the national industrial standardizing bodies was held in Switzerland, where thirteen of the more important industrial nations of Europe and America were represented. Important progress was made in developing co-operation between the various national bodies, particularly in regard to the early release to each other of

information on work in progress. Information on the status of all projects in hand is now regularly interchanged between the various bodies. Provision was made for continuing the work of the conference on the many problems of common interest through a continuing loose-knit organization.

There are now national industrial standardizing organizations in sixteen countries: Australia, Austria, Belgium, Canada, Czecho-Slovakia, France, Germany, Great Britain, Holland, Hungary, Italy, Japan, Norway, Sweden, Switzerland, and the United States. Of these, the work in Great Britain, Germany and the United States is the most extensive, as would be expected from the scale of the industrial development in these countries.

The extensive standardization work going on in Germany continues to present many interesting phases. Some of these were outlined in a recent bulletin of the American Engineering Standards committee. Practically every important manufacturing concern in that country is actively engaged in the work, and more than a thousand compañies have formal standardization organizations within their own works. Approximately seven hundred national German standards have been approved by the central national standardizing body. These are only standards in which several industries are concerned. Standardization engineering is now a recognized profession in Germany. Some of the consulting engineering firms specialize on standardization work. Through their work on trade catalogs, these consulting engineers, among other things, are introducing standardization into sales policies and sales organizations.

Of interest not only in its relation to international standardization, but also on account of its bearing on the use of specifications in foreign trade, is the resolution passed by the last conference of the pan-American union, where it was decided "That a conference on standardization of specifications of materials, tools, machinery and supplies to be held.... with a view to reaching agreements which may be embodied in inter-American conventions on this subject." This projected movement will be watched with great interest by American industries.

Standardization continues to play a more and more important role in the activities of trade associations. The subject is treated at length in the book on "Trade Association Activities" issued by the Department of Commerce during the year. It is of more than passing interest that the Supreme Court in a recent decision in regard to trade association activities, explicitly recognized standardization as being in the public interest.

PROGRAM WINTER SECTIONAL MEETING

THE winter sectional meeting of the American Society for Steel Treating will be held in Rochester, New York, on Thursday and Friday, January 31 and February 1, with headquarters at the Hotel Seneca. The tentative program for the meeting is as follows:

11:00 a.m. Registration and technical papers, at Seneca hotel.
12:30 p.m. Luncheon at Seneca hotel.
2:00 p.m. to 5:00 p.m. Four technical papers.
6:30 p.m. Joint banquet of Rochester chapter of A. S. S. T. and the Chamber of Commerce at the Chamber of Commerce building.

The order in which papers will be presented has not yet been arranged. However, the following four papers have been definitely scheduled:

Prof. H. M. Boylston, head of Department of Metallurgy, Case School of Applied Science: "CONTROL OF PRODUCTION BY SCIENTIFIC METHODS."

A. H. d'Arcambal, chief metallurgist, Pratt & Whitney, Hartford, Conn: "CARBON TOOL AND HIGH SPEED STEELS USED IN THE MANUFACTURE OF SMALL TOOLS."

J. V. Emmons, chief metallurgist, Cleveland Twist Drill Company: (Subject to be announced later.)

Dr. Ancel St. John, of the research laboratory, Union Carbide & Carbon Co., Long Island City: "PRESENT DEVELOPMENTS IN THE X-RAY FOR CRYSTAL ANALYSIS."

Two other papers have been promised, but definite indication of the subjects has not yet been received.

The meeting in the evening is to be preceded by a joint banquet of the Rochester chapter of the A. S. S. T. and the guests, with the Rochester Chamber of Commerce at the Chamber of Commerce building. It is expected that from 300 to 500 will be present at the dinner. Mr. J. J. Desmond, chairman of the Rochester chapter of the A. S. S. T. will be master of ceremonies, and Doctor Rush Rhees, president of the University of Rochester, will act as toastmaster. The principal address of the evening will be by Doctor George K. Burgess, president of the A. S. S. T. and director of the Bureau of Standards, on "The Relation of the Government to Industry."

Indications at present are for a very large attendance, and the meeting is going to be of very high caliber. All who can possibly arrange to come, should do so.

Please make your hotel reservations early with the hotel management, the rates for which are as follows:

Rooms equipped with	Single	Double
Hot and cold running water	$2.50	$3.50
Shower baths	2.50	4.00
Shower baths	3.00	4.50
Shower baths	3.50	5.00
Tub baths	3.00	5.00
Tub baths	3.50	5.00
Tub baths	4.00	6.00
Twin beds and shower baths		5.00
Twin beds and tub baths		7.00
Two double beds and tub bath (4 persons)		10.00

Parlors, $3.50 and up, per day.

In making reservations it is important that the hour of arrival be given, as reservations are not held after 10 p. m., except on special request.

Kindly make second choice, in the event your first choice of rate is not available.

LIQUID HEATING BATHS

MUCH interest on the part of many metallurgists and heat treaters, has been given to the study of liquid bath heating mediums. The lead bath has been in vogue for many years and has proven itself worthy of the extensive use to which it has been given. However, the lead bath has its limitations just as do most other tools with which we work. Experience has taught us that it usually requires a special tool to do a special type of work and although it is possible to cross-cut a piece of lumber with a rip saw it is not possible to obtain the workmanlike type of work that should result through the use of a cross-cut saw. So with the salt baths, they are tools with which to accomplish a desired kind of work. They have their particular use just as the cross-cut saw and the drop-forge die. When used in places outside of their scope the results may not be satisfactory.

Mr. Tour in his paper pertaining to salt baths and containers has given much time and study to this problem. He has, through laboratory and actual shop practice, made many tests and observations upon which he has based his deductions respecting the chloride salt baths for heating steel at 1600°F.

The difficulties that were encountered in using chloride salt baths are clearly outlined and the deleterious effect that contaminated or impure salt baths have upon the steel being treated as well as upon the container in which the salt is heated, is covered in much detail by the author. Of course, the possible decarburization of the steel undergoing heat treatment is by far the most decided disadvantage in the use of the salt baths described by Mr. Tour. As brought out by the author and others, it is often the thought that when a piece of steel is brought out of the hardening room bright and free from scale or discoloration that the tool has been properly treated. This idea, of course, may be erroneous as shown in this paper. Salt baths, beyond all question of doubt, when of the proper composition are a very valuable tool for the hardener and their use is rapidly coming into adoption in many of our hardening rooms.

SALT BATHS AND CONTAINERS FOR HARDENING

By Sam Tour

Abstract

The subject of salt baths for the heating of steel tools and parts is discussed in considerable detail in this paper. A simple method of desulphurizing of a salt bath is given.

The decarburizing effects of chloride salt baths at 1600 *degrees Fahr., upon the materials being treated are discussed in detail. Photomicrographs of steels heated in various types of salt baths accompany this paper.*

General principles in regard to design of furnaces for salt baths are laid down.

It is pointed out that high-chromium alloy containers deteriorate from the action of heated chloride salt baths. Cast steel and pressed steel pots appear to be the best containers.

Introduction

SOMETIME ago,[1] the writer contributed an article entitled *Salt Baths for Heat Treating* in which a number of different combinations were discussed and the requirements of a satisfactory hardening bath given. Since then, W. J. Merten[2] has discussed the use of *Molten Salts in Heat Treating* and has laid particular stress upon a barium chloride-sodium chloride bath desulphurized with manganese or ferromanganese. From a study of these two papers, it would appear as though they were written from two different viewpoints. The writer stated that for treating complicated pieces of high-grade steel, other than high-speed steel, a salt bath should be available that will melt at as low a temperature as possible. Mr. Merten states that the fusion point of the salt bath should be reasonably high so as to make use of the added advantage presented in the poor heat conductivity of the solid crystal which retards the heat transfer and therefore reduces the rate of heating of the steel. Mr. Merten deals, however, with case hardened cam shafts of no great in-

1. *Transactions*, American Society for Steel Treating, November, 1922.
2. *Forging and Heat Treating*, March, 1923.

A paper presented at the fifth annual convention of the Society, Pittsburgh, October 8-12, 1923. The author, Sam Tour, is metallurgist, Doehler Die Casting Co., Brooklyn, N. Y.

trinsic value and, aside from surface hardness, presenting no real problems for the heat treater to solve. The writer referred to the use of a salt bath for treating complicated dies and tools of considerable value and made from either plain high carbon or alloy steel of high grade. Such tools and die blocks are usually of intricate shape with heavy and light sections adjoining one another and often bearing impressions with very sharp corners. Due to the great liability of cracking of such pieces, especially if heated too rapidly, one would not practice the putting of cold pieces into a fused bath already up to heat.

It is fortunate that no appreciable scaling takes place below 1100 degrees Fahr. and that, therefore, such pieces can be preheated slowly up to that temperature in an open furnace and transferred when hot to a molten salt bath. A number of experimenters have found that the questions of growth and shrinkage upon heat treating are in some way or other associated with or influenced by the rate of heating. It appears as though this is especially true in regard to the rate of heating through the critical range. This is one reason why it is usually not advisable to plunge a die-block, even preheated to 1100 degrees Fahr., into a molten salt bath at 1500 or 1600 degrees Fahr. To avoid any sudden temperature changes in the heating of the steel, for hardening, it would be advisable to preheat in an open furnace at the desired rate from cold to 1000 or 1100 degrees Fahr., transfer to a molten salt bath at this temperature and then raise salt bath temperature at the desired rate to the quenching temperature. This, of course, means slower operation and intermittent operation, but nevertheless, gives the desired results.

If this intermittent method is not used, if rate of heating through the critical range does not require control, and if, therefore, the bath is run continuously at the quenching temperature, then the fusion point of the salt bath is not one of very vital importance. Of course, the higher the fusion point, the greater will be the overheating of the pot upon starting up the salt bath. It is during this heating and melting period that usually the greatest damage is done to the container.

Barium Chloride—Sodium Chloride

Regarding the barium chloride-sodium chloride bath used by Merten, the writer stated that this mixture was unsatisfactory due to its high melting point, its tendency to lump and form soft spots on quenching in oil, and to the difficulty in cleaning the surface of the steel after quenching. Merten wanted a high melting point and quenched in water, so avoided these disadvantages. For his work, any number of salt baths could have been used with equal success.

Barium Chloride—Calcium Chloride—Sodium Chloride

After trying many salt mixtures, as described previously, and after operating salt baths for thousands of hours, the writer has had greatest success with a bath composed of approximately 33 1/3 per cent each by weight of dry barium chloride, calcium chloride and sodium chloride. Possibly, some investigator has determined the ternary diagram for this system, but the writer has been unable to locate it as yet. To determine it independently would be a laborious proceeding and one which would require great enthusiasm to undertake. Considerable experience has shown, however, that the mixture of approximately equal weights, functions very satisfactorily for temperatures up to 1650 degrees Fahr. This mixture does not freeze at one particular temperature, thus indicating that it is not of an eutectic composition. It is, however, still molten at a temperature around 1100 degrees Fahr. and, therefore, can be used quite satisfactorily in an intermittent process where it is necessary to preheat the steel and then raise bath and steel to the desired quenching temperature which may be up to 1650 degrees Fahr. Above 1650 degrees Fahr., the bath fumes excessively. This mixture made up from salts free of sulphate, has no pitting action and has very good cleaning-off properties after quenching in oil. If the salts are not free of sulphate, the bath must be desulphurized.

Desulphurization

Merten attempted to desulphurize with low sulphur hot rolled open-hearth steel. He seemed to conclude that iron

sulphate formed and then broke down to sulphur dioxide and magnetic oxide of iron. Using manganese or ferro-manganese, he apparently believes that he forms a sulphide instead of a sulphate and that this sulphide is stable and can be removed as a slag, thereby desulphurizing the bath. Merten also ascribes decarburization properties to magnetic oxide of iron and therefore attributes decarburization to what he believes is the source of the magnetic oxide, namely sulphates, and he inseparably associates pitting with decarburization. The writer's experience has not been in agreement with the above.

Desulphurization is readily, thoroughly, and satisfactorily accomplished by means of clean cast iron chips. The sulphur content of the cast iron is of no appreciable importance. As stated previously, by the writer, various salt mixtures when first made up, have a tendency to pit and not to clean off well, and after reheating several times, seem to lose this pitting property and to gain cleaning-off properties. The cause and cure for this can best be explained by a description of actual experience.

A quantity of salt mixture was made up from new shipments of salts received. The resultant mixture had a very decided pitting action which did not cease even after five consecutive days of heating. A quick analysis of the mixture showed that the proper proportions of salt were used in making it up. A peculiar incrustation was noticed upon the cast-iron pyrometer protection sleeve which had been hanging in this salt mixture during the runs. An analysis of this incrustation showed it to carry a considerable quantity of sulphide as evidenced by the liberation of hydrogen sulphide and free sulphur on treatment with acid. This called attention to the question of sulphate contents of the shipments of salt. Analysis showed the shipment of sodium chloride to be free of magnesium but to carry 0.8 per cent of sulphate. To prove whether or not sulphate was the cause of pitting, poor cleaning qualities and this incrustation, a small amount of mixture was made up using chemically pure sodium chloride. This mixture had absolutely no pitting action on very first melting and cleaned off well. Chemically

pure salts are expensive and it was found that sodium chloride free from sulphate was not available in any other form and that the best obtainable commercially would contain up to 0.2 per cent sodium sulphate. A small amount of mixture was made up using the latter grade of sodium chloride and it was found that the mixture needed to be heated a second day before good cleaning-off properties were developed. To economically use this grade of material or even a poorer grade of material, it was therefore necessary to devise some desulphurization process.

Since there is a limited amount of sulphate present in the salt and since this sulphate must have been the source of the sulphur in the incrustation around the cast-iron pyrometer sleeve, it was assumed that if sufficient iron were added to carry this reaction to the point where all the sulphate were used up, the pitting action must necessarily cease. On this assumption, about 15 pounds of carefully dried cast-iron chips were added to 200 pounds of salt mixture which had this excessive pitting property. The pitting ceased at once and the mixture had very good cleaning-off properties. Further tests showed that cast-iron chips will effectively "cure" a salt mixture containing as high as 1.0 per cent of sodium sulphate. No tests were carried out on higher percentages than this.

The cast-iron chips added to desulphurize the bath settle to the bottom of the pot in the form of a sludge. This sludge is harmful from the standpoint of heat efficiency and effective depth of pot, but does not have the objectionable pitting properties ascribed to it by Merten. With a properly designed salt pot furnace, a sludge, even of a refractory nature, does not introduce great trouble in regard to heat efficiency. A salt pot furnace should be so constructed as to heat the pot from the sides and not from the bottom It should preferably heat the top of the pot first so that on melting down the solid salt, the top will melt first and relieve the stresses set up by the expansion of the solid mass beneath. Direct impingement of flame on pot should also be avoided. With burners set tangentially near the top or flange of the pot and the furnace vented at the bottom,

cast iron chips or any other sludge in the bottom of the pot need not cause great concern.

The barium-calcium-sodium chloride salt bath described above, functions equally well in cast iron, pressed steel, or alloy steel pots. If, however, a piece of steel is hung in this salt bath or any other chloride bath, so as to have part of it in and part of it out of the molten mixture, a corrosive or pitting action results at the surface of the bath. This action appears to be due to a reaction between the chlorides, the steel and the oxygen and moisture of the atmosphere. No way has been found to eliminate this trouble, although no particular effort has been made in that direction.

This ternary mixture is not without its disadvantages. It contains calcium chloride and, therefore, gives the same trouble ascribed in the previous article to calcium chloride in other mixtures. In this regard, however, it is not as objectionable as the calcium chloride—sodium chloride mixture. In fact, the main value of this ternary mixture over a binary mixture of 72 per cent calcium chloride, 28 per cent sodium chloride, is in the decreased amount of fuming at high temperatures. Steel after quenching from any bath containing calcium chloride and before tempering, must be carefully washed to remove traces of salt. Furnaces must be provided with good hoods and exhaust pipes leading outside of the building in order to keep to a minimum the quantity of calcium chloride fumes escaping into the room.

Decarburization

In dealing with, considering and comparing different salt bath mixtures and in studying the relative values of various methods of hardening, we are usually apt to pass judgment upon visual appearance of the work. Too often, we consider work well done and the method satisfactory if the original surface comes through unpitted and unscaled. With a salt bath in proper operation, a polished die-block or tool can be treated without a single blemish or discoloration of the surface resulting. Does this mean the work is satisfactory? In hardening tools, dies, etc., what we are interested in is carburization and decarburization. Scaling

is an important factor ordinarily only when fine engraving and accurate dimensions are involved. Many associate decarburization with scaling and the first thought is "no scale, no decarburization." Many hardeners almost subconsciously think "a clean piece is a good piece." Salt baths leave clean bright surfaces on pieces treated in them, but many salt baths have a decarburizing action and the work has a soft skin. The ordinary test for this is the file, but it is by no means the most illuminating test. In looking for decarburization, the microscope is a great aid.

Pitting and decarburizing hold no relation to one another in a chloride salt bath. Fig. 1 is a photomicrograph at 75 diameters of 0.50 per cent carbon, chrome-vanadium steel heated for four hours at 1600 degrees Fahr., in a newly made up salt bath with pitting properties. Fig. 2 is a similar photomicrograph of a piece of the same steel heated the same length of time in the same salt bath after it had been "treated" with cast iron chips and had ceased to pit. Fig. 3 is a similar photomicrograph of a piece of steel heated the same length of time in the same salt bath after it had been in use for some 50 hours. Fig. 4 is a photomicrograph of a similar piece of steel heated in a salt bath which had been in operation for some 500 hours. All of the pieces were cooled in lime. Special studies were made to be sure that no decarburization was caused by the method of cooling or method of annealing used. From an inspection of these photomicrographs, one clearly sees that as the bath becomes older its decarburizing action increases. This may be ascribed to a solution of oxygen and carbon dioxide from the atmosphere or to the formation of oxides or carbonates by the decomposition of the chlorides at the surface of the bath in contact with the atmosphere. The possibilities were considered of counteracting this decarburizing effect by the addition of a small amount of sodium cyanide. It was found that even a fraction of one per cent of cyanide yielded work with a "case." After a few days operation, the cyanide seemed to be completely decomposed and decarburizing action again occurred.

This decarburizing action is often not as important as

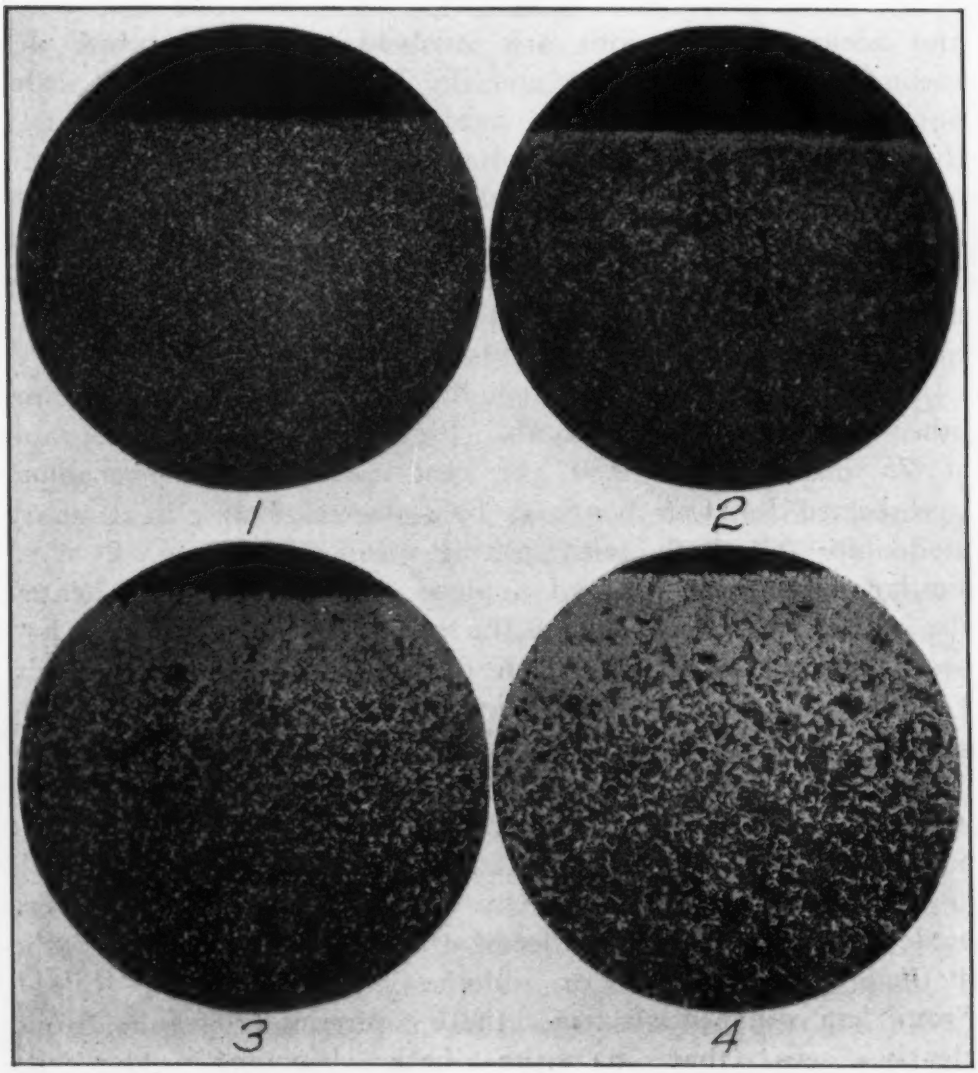

Fig. 1—Chrome Vanadium Steel heated for 4 hours at 1600 degrees Fahr. in new untreated salt bath, cooled in lime. x 75. Fig. 2—Chrome Vanadium Steel heated for 4 hours at 1600 degrees Fahr. in new but treated salt bath, cooled in lime. x 75. Fig. 3—Chrome Vanadium Steel heated for 4 hours at 1600 degrees Fahr. in salt bath 50 hours old, cooled in lime. x 75. Fig. 4—Chrome Vanadium Steel heated for 4 hours at 1600 degrees Fahr. in salt bath 500 hours old, cooled in lime. x 75.

one might gather from the above. The work shown in the photomicrographs was held at temperature for 4 hours. Only on very heavy blocks would any such soaking time be encountered. Fig. 5 is a photomicrograph of a piece held only 1 hour which is in itself much longer than is necessary to "soak" the ordinary piece.

Decarburization often occurs when we least expect it

anyway. It is quite common practice to pack work in charcoal and cast iron chips for annealing. The work comes out clean and bright and we usually "ask no questions." Fig. 6 is a photomicrograph at 75 diameters, of a similar piece of steel to those shown in previous photomicrographs, but packed as stated and held at 1600 degrees Fahr. for 4 hours and allowed to cool very slowly in the furnace. Fig. 7 is a duplicate piece, but cooled in lime instead of in the furnace.

Containers

One of the largest sources of trouble and expense in the operation of a salt bath is the question of pots or containers. A few references have been made above to the question of furnace design. Too often furnaces are considered only from the standpoints of first cost and fuel consumption. In salt bath work, the furnace must also be considered from the standpoint of the container.

That direct impingemet of flame is to be avoided is obvious. That combustion chamber atmospheres must be controlled is not always so obvious. Many makers of chromium alloy heat resisting pots claim that their alloys thrive in oxidizing atmospheres and as long as plenty of air is used, one need not worry about the effect on the container. The writer's experience, however, has not been favorable to these alloy containers as will be described below. In using cast iron, cast steel, or pressed steel pots, furnace atmospheres are important. Oxidizing conditions should be avoided. Furnaces should be equipped with burners which allow of easily adjusting the proportions of air to fuel. This proper proportioning is necessary during all stages of the operation of the furnace and for this reason burners arranged for one valve control are often advantageous. Although many burner equipments are capable of being adjusted to give the desired atmospheric conditions, these capabilities are too often neglected in the heat treating room. One is always too prone to carefully adjust the air and fuel valves on lighting up the furnace and thus consider he is controlling his atmosphere, but as the furnace comes up to heat, the tendency is to decrease the fuel supply and not the air. From this point on, the furnace atmosphere is oxidizing.

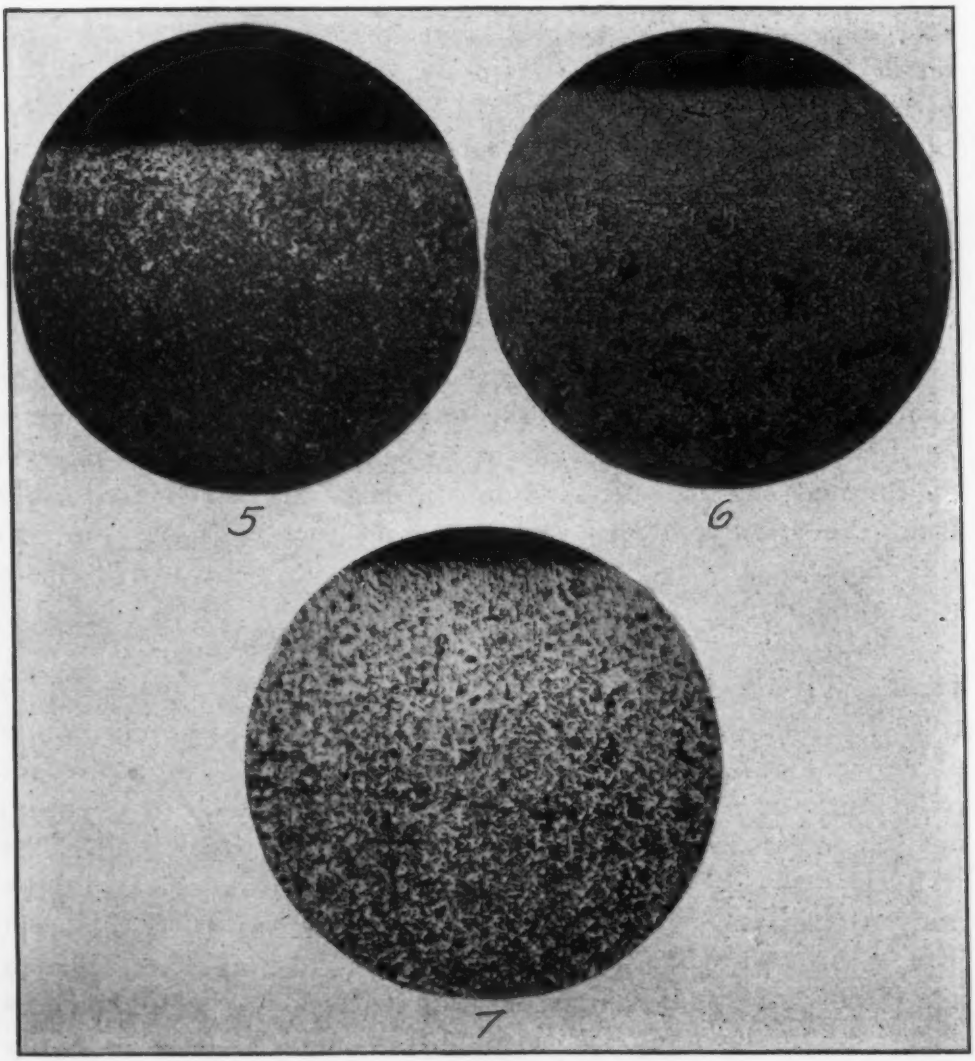

Fig 5—Chrome Vanadium Steel heated 1 hour at 1600 degrees Fahr. in salt bath, cooled in lime. x 75. Fig. 6—Chrome Vanadium Steel heated for 4 hours at 1600 degrees Fahr. in box packed with charcoal, cooled in furnace. x 75. Fig. 7—Chrome Vanadium Steel heated for 4 hours at 1600 degrees Fahr. in box packed with charcoal, cooled in lime. x 75.

Another item in furnace design to be considered in connection with containers is location of burners, vents, and zones of maximum heat input. Many pot furnaces are built so as to vent at the top around the flange of the pot. This type of furnace is not desirable for salt baths because invariably, salt gets into the combustion chamber and at the high temperatures prevailing there, has a detrimental action on the furnace lining and the container. If the furnace is

not allowed to vent around the flange of the pot, then side or bottom venting must be resorted to. Vents and burners should be so arranged as to place the zone of maximum heat around the upper level of the salt in the container. This is desirable both from the standpoint of melting the salt in the "heating up" period and of maintaining the temperature during the day. As most of the heat loss during operation is by radiation from the top of the bath, this should be the zone of maximum heat input. Containers are often caused to bulge and to crack by the internal pressure resulting from expansion of the solid salt. By having the salt hottest at the top, it melts there and thus relieves the pressure below. In operating a salt furnace which is hotter at the bottom than at the top, the salt becomes molten at the bottom while a solid crust still remains on top and the pressure increases until either the pot expands, the crust breaks, or the pot breaks. The writer has seen the crust break in this manner and molten salt shoot several feet in the air like a miniature volcano or geyser.

Having proper furnace conditions, the container must be selected with a view toward its life and the heat efficiency of the installation. The thinner the walls of the container the higher will be the heat efficiency, the shorter will be the time for melting and getting up to heat, and the easier it will be to control the bath temperature. The life of a container is dependent upon its resistance to the action of the bath, to the strains set up on heating and cooling, and to the amount of external oxidation and chemical attack. The external features are primarily furnace design and operation questions as described above. The so common practice of cooling a bath when the temperature gets too high, by shutting off the fuel and leaving the air on, should be carefully guarded against. Strains during heating and cooling arise from three sources. First, those due to expansion and contraction of the container itself. Second, those due to expansion of the solid salt within, during heating. Third, those due to fluid pressure of the molten salt. To these might be added, in the case of cast iron pots, the matter of permanent growth. Strains due to expansion and contraction of the metal of the container, eventually causing cracks, can best be re-

duced by the practice of slow heating and cooling and by the use of thin-walled containers. Strains due to expansion of the solid salt within are minimized, as described above, by furnace designs having hot zones at the top. Strains due to fluid pressure of the molten salt cannot be eliminated, but can be counteracted by using containers which retain considerable strength at the temperature of operation. The excessively heavy sections required in cast iron pots, their weakness at high temperatures, their low resistance to strains during heating and cooling, and their property of growing as a result of heating, make them undesirable containers for molten salt baths.

The requirements of a container can therefore be summarized somewhat as follows:

(1) It should be as thin-walled as possible.
(2) It should be as strong as possible at the operating temperature.
(3) It should be as resistant to oxidation as possible.
(4) It should not be of cast iron.
(5) It should not be acted upon by the sale mixture.

Considering the above, we are left to choose between pressed steel, cast steel, and alloy pots. A majority of the alloy pots on the market are cast of chromium heat resisting alloys. The writer has found that these alloys are attacked by molten chloride baths. The attack is apparently of two-fold nature; first, a decarburization, and second, an intercrystalline or intergranular penetration and deterioration. Several pots which had failed by developing leaks after approximately 500 hours service apiece were broken and investigated. The fractures of the walls, about 5/8 inch thick, showed a discoloration fully half way through all over and all the way through at the places where leakage had developed. A manufacturer of this type of alloy attributed this discoloration to the compound sodium chromate and after a microscopic study, they reported that there had been an intercrystalline deposition of some sort. These same conditions were found on both fine and coarse grained cast-

ings. No intercrystalline deterioration of this kind has been found with pressed steel or cast steel pots, although some decarburization does result. Where pots of cylindrical shape can be used, experience seems to favor the pressed steel pot with flange.

SUMMARY

For fine heat treating work on delicate and expensive pieces, an intermittent or "batch treatment" is necessary. A good salt bath for a temperature range from 1150 to 1650 degrees Fahr., consists of equal parts of barium chloride, calcium chloride and sodium chloride. Desulphurization is accomplished by use of cast iron chips. Pitting and decarburization do not go hand in hand. Many baths develop decarburizing properties with use. Decarburization, however, is usually quite small. Furnaces should be properly designed and operated to obtain maximum service from containers. High chromium alloy pots deteriorate from action of a chloride bath. Cast steel and pressed steel pots seem to be the best containers.

Discussion of Mr. Tour's Paper

CHAIRMAN d'ARCAMBAL: A paper of this nature is of considerable value because the results obtained by Mr. Tour have been gained through actual work in the hardening room. This paper contains practical information as differentiated from laboratory experimental work.

W. J. MERTEN: We are all indebted to Mr. Tour for the thorough way in which he has attacked this problem. My own experience in salt bath heating has been somewhat different. We had a specific problem to contend with, which has been described in the paper referred to by Mr. Tour. There are some phases of this work I would like to bring out at this time, that are not entirely in accordance with Mr. Tour's opinion of the actual tests as conducted. Unfortunately I have not had time to make any preparation in response to Mr. Tour's paper, a copy of which was presented to me yesterday, but had I had the opportunity I would have gone into it much more thoroughly than I am able to at this time. I think the contribution is one of the best that has ever been presented to us on the subject of salt bath heating. The literature on this subject is meager and incomplete at the best.

The particular salt bath used in my work, to which Mr. Tour is referring, developed a heavy sluggish mass in the bottom of the container which, upon analysis, proved to be very magnetic, confirming the suspicion

that it was a magnetic oxide of iron. At the present time I do not recall the chemical equations which I worked out and published in the paper mentioned, however, I still believe that they are correct.

The heats developed in the bottom of the container were of a somewhat higher temperature than those Mr. Tour has evidently considered in his case. I do not think I would have expected any sulphates present at the heats which we encountered in my work. The temperature of the bath was probably 1400 degrees Fahr. in the top layers and we were unable to get any heat through it at all, even though the refractory mass on the bottom showed a white heat, which would, I am sure, decompose a sulphide. However, we are at this time running tests on salt baths for high-speed steels, which will be conducted along the suggestions and points we have obtained from Mr. Tour's paper. Probably we will be prepared to conduct the tests somewhat more intelligently than we previously had time for. We were engaged on production work which as you may well know is not quite the same thing as preparing an individual die. Mr. Tour has all the facilities and all the time that he may desire to make such tests, while in our division, the production department expects results in 24 to 36 hours. For that reason there might be some slight discrepancy and some slight fault with some of the deductions that have been made there. I, however, still maintain that they are correct.

The method of heating of a pot of the type used, was probably objectionable. While we did have a whirling flame for heating the pot, from the bottom, apparently there was not the proper heat distribution which should have been attained for proper heating, and I thoroughly agree that Mr. Tour has hit upon the solution, by heating his containers in a more even and homogeneous way in order to get proper results. We employed, I believe, a barium chloride-sodium chloride bath, and I have a suspicion that we tried the same method to recarburize our bath by adding a small amount of cyanide, which worked out for a certain length of time and then showed the same decarburization effect on the steel. This I attributed more to the reaction of a nitride forming a nitrate with the oxides present, and consequently a decarburization. However, I cannot conceive of a decarburization by the action of chlorine gas. I do not quite see how in a chloride bath, unless with the formation of some oxide compound, you can decarburize the surface of any steel. You can by a combination of reactions form oxychloride compounds conducive of that particular decarburizing effect. Carbon oxides are then formed, such as the monoxide CO or the dioxide, CO_2. I do not know which particular gas may be formed. I am inclined to say that this subject needs some thorough investigative work before I entirely accept Mr. Tour's analysis of the particular condition. However, Mr. Tour's contribution certainly ought to be a stimulus for further research along those lines.

SAM TOUR: I have not gone into a long line of chemical reactions, trying to explain the how and why of all this decarburization. I was not particularly worried about the mechanism of decarburization, it was worry enough to know it was there.

Mr. Merten brought out that in his operations he had a sludge at the bottom of the pot which was very refractory, and he probably heated that hot enough to decompose sulphates and sulphides. I would dislike to condemn a salt bath as being a pitting bath or anything else if I had a portion of that salt bath heated to a white heat.

I would like to call your attention to the fact that in this paper I refer only to a salt bath operating at 1600 degrees Fahr. A salt bath might decarburize very extensively at 1600 degrees Fahr. and might be perfectly good at 1425 to 1450 degrees Fahr. for plain carbon steel. At 1600 degrees Fahr., these chloride baths decarburize. I do not say they do at 1500 or 1450 degrees Fahr. It is quite possible that the decarburizing action does not go on so rapidly at the lower temperatures.

In regard to the reactions that take place, it is true it would be hard to figure out how a chloride in itself would cause decarburization. It is also true, however, that any molten chloride reacts with the moisture of the atmosphere to liberate chlorine and form the oxide; the oxide then may react, may stay as oxide or may react with CO_2 in the atmosphere to form the carbonates, and the carbonates may do the decarburizing. That is a possible explanation.

E. C. BAUM: Inasmuch as there has been no chemical analysis made, I would suggest making a chlorine analysis to find out whether carbonyl chloride has formed. I had in mind we might have a combination of carbon with the chlorine liberated.

SAM TOUR: I have had analyzed many samples of the salts. A breakdown occurs and also a variation in chloride content, but one cannot ascribe it as due to a formation of carbonyl chloride, because salts are continuously being lost by volatilization. Not knowing the relative vapor pressures of the various salts that are used in the baths, the amounts lost by vaporization are unknown and a change in the relative percentage of the chlorides in the bath cannot be attributed to any one cause.

E. C. BAUM: I was trying to figure out some reaction of carbon in the steel forming carbonyl chloride. I was just offering this as a suggestion.

SAM TOUR: So far as I know, the only other things we have found in there besides the chlorides were the oxides.

A. L. DAVIS: I would like to ask Mr. Tour whether the analysis of the salt bath indicated that the bath gradually accumulated iron in solution. Iron could easily be a carrier of carbon or oxygen.

SAM TOUR: Since we decarburized with cast iron chips, there is no question but what there is plenty of iron there. An analysis for iron would not determine whether the iron is due to iron in solution in the salt or whether it is due to suspended particles of cast iron.

A. L. DAVIS: Prior to adding cast iron chips, does the salt bath gradually accumulate a certain amount of iron?

SAM TOUR: I do not know, I have not attempted to find out.

L. A. LANNING: I assume from Mr. Tour's talk that he has found no method of overcoming decarburization of the chloride bath. Is that correct?

SAM TOUR: That is correct for temperatures of 1600 degrees Fahr.

C. S. GORDON: In some experimental work we were doing, we were quenching some high-speed steel in a saltpetre bath which was at a temperature of about 1000 degrees Fahr., in quenching the high-speed steel a chemical action took place and the high-speed steel disappeared. I would like to have somebody tell us what happened.

SAM TOUR: I do not know what the explanation is. I have known of treating high-speed steel in nitrate baths, that is, for the tempering operation, at 1100, and tool bits that were being treated came out badly eroded. I don't know what the reaction was, but it was really there.

T. H. NELSON: I think today the steel treater, when he hears the name of Sam Tour connected with salt baths, sits up and takes notice. Personally, I think that Sam Tour has today, perhaps more than in any other of his articles, emphasized a feature that we should all carry home, and that is that he has practically stated that he does not consider the solution of the difficulties outlined possible by the use of any particular kind of pot, or the use of any particular brand or mixture of salt; because no brand or mixture of salt can for any length of time remain constant in service. I know from the depth of thought given to the paper that it has been absolutely convincing to all of us that Mr. Tour has made a very deep study of it.

I would like Mr. Tour to say whether he feels that with the type of bath in which he has carried out his experiments it is possible by continued additions, or continued modifications while it is in operation, to maintain a bath which will not seriously pit any more than it will seriously decarburize, and if so, is he prepared at this time to give us a little more detailed information. In other words, what would the author's final recommendations be to the men in the hardening shop with regard to the ideal composition of a salt bath hardening furnace (for temperatures not exceeding 1600 degrees Fahr.) and the recommended periodic regeneration or adjustments by addition to keep a bath in the best possible condition for use. I should certainly not like to sit down without congratulating the author on a paper which I realize must have been somewhat difficult to present, inasmuch as the society embraces quite a number of special alloy manufacturers as well as advocates of a variety of hardening salts. The manner in which the paper has been presented is such as to reflect credit upon the author, for without giving offense to anyone, he has given the benefit of his time and thought, together with a whole lot of practical experience, to the society in general, which is a very fine spirit indeed.

SAM TOUR: It is pretty hard, in this kind of work, to make any far-sweeping statements against salt baths, especially when there are people

who make a living selling these salt baths, and especially when those people happen to be your friends.

I have attempted to stay away from any reference to salt baths at present on the market, by any name. I would not say that it is impossible to get a salt bath that would not decarburize steel. So far as I know it is impossible to get one that will not decarburize at 1600 degrees Fahr. I believe it is possible to get one that will not decarburize steel at 1450 degrees Fahr., which is the ordinary, plain carbon steel treating temperature. At 1600 degrees Fahr., I have yet to find any bath, carbonate, chloride, fluoride, sulphate or anything else that will not decarburize steel.

M. H. MEDWEDEFF: I would like to ask Mr. Tour what the possible objection would be to the addition of cyanide at such times as it becomes used up. The effect of carburizing would be so slight upon a die it would not have any possible effect upon the quality of the ultimate die.

SAM TOUR: Why not treat all your dies, then, in the common, ordinary cyanide pot? Why worry about the chloride bath at all? Why not use cyanide-chloride-carbonate mixture as sold on the market?

M. H. MEDWEDEFF: In a normal salt bath, with one-half of one per cent of cyanide, you would not expect to get as much carburization.

SAM TOUR: So far as I know I have not been able to find any appreciable difference between the carbon content as a result of cyaniding with a mixture of 8 to 10 per cent of cyanide or 98 per cent cyanide. So far as I know the case is the same. Whether that straight line relation holds on down to one-half of one per cent, I do not know.

M. H. MEDWEDEFF: How much of a case would you get?

SAM TOUR: I do not know. In our work I would not use a die that had any case, even 0.0001 of an inch.

M. H. MEDWEDEFF: Mr. d'Arcambal would you care to comment on this subject?

CHAIRMAN d'ARCAMBAL: I have had practically no experience with salt baths, but I would be afraid, that even with small amounts of cyanides, you would obtain nitrides, and with the nitrides you would probably obtain brittleness. Also you would not know when to add the cyanide again. When you have to keep on adding cyanide to keep up your bath, that means that every once in a while you are going to obtain soft tools due to the cyanide being exhausted and that is quite expensive.

SAM TOUR: I endeavored to stay away from the subject of nitrides, but it is there, of course.

M. H. MEDWEDEFF: This is a regular process in the work on bolts, without any ill effects on the bolts themselves, so I would expect that on a die of heavy dimensions the effect would be so small as not to cause any deleterious effect.

CHAIRMAN d'ARCAMBAL: The greatest objection would be,

that you would never know when your bath was exhausted. You would have to keep on adding cyanide.

SAM TOUR: Let me try to go through the reaction. You add one-half of one per cent of cyanide today. That breaks down to sodium carbonate, say in ten hours. The next ten hours you add another one-half of one per cent of cyanide. That breaks down. You started with a salt bath that did not have any carbonate in it; you are adding every ten hours one-half of one per cent of sodium carbonate which is a strong oxidizer and decarburizer; just as soon as you get a large percentage of that in one of these salt baths you get scale, as well as decarburization. You are intentionally adding cyanide, which will break down and form carbonate. Just as soon as the cyanide runs out, then you will get scaling, as well as decarburization.

H. B. KNOWLTON: I should like to call attention to the action of the chloride bath due to moisture of the air. I should also like to bring up the point of moisture added by the addition of the chloride itself. Several years ago I was working in a hardening room, and we were having a great deal of trouble with our salt pots at a temperature of 1600 degrees Fahr., not so much as to the pitting of the work, but the pot would not stand up, the chloride would cut through. We went after the question of moisture. At first thought it does not sound reasonable, that the moisture will persist, perhaps, in a temperature of 1600 degrees Fahr., but you are continually adding fresh salt. This was a barium-potassium-sodium chloride mixture. We found on a laboratory scale with a small piece of wire, weighed on a mechanical balance, that it made a great difference in the loss of weight of that wire in a hot furnace whether we added previously dried salt or whether we added some that we artificially increased the moisture content of. We obtained, I believe, a loss of about ten per cent on the weight of that wire. This loss may not continue constantly, but at least when new salt is supplied to the pot a certain amount of superheated steam formed, which, combined with the chloride, is extremely strong in its reaction. I think that would enter into the shortening of the life of the pot.

SAM TOUR: So far as I know no one practices the addition of salt to a molten bath, in that way. Personally, I would be afraid to do it. Always, when we make additions to the pot, we make them as additions of salt mixtures previously melted, and therefore all the water driven off; and we never worry about the life of the pot in the furnace in which we make up new salt—that pot goes very rapidly, all kinds of things happen to it. The barium chloride on the market very often carries two molecules of water of crystallization. Potassium chloride is quite hygroscopic and if allowed to stand around it will absorb enough water to cause trouble. These salts should be very carefully preheated and all users of salt baths that I know of, carry out this procedure.

M. H. MEDWEDEFF: Unfortunately I did not hear the entire paper. Do you preheat your dies before putting them into the salt bath?

SAM TOUR: I went through all that rather in detail. I absolutely

believe the die should be preheated to about the temperature of the salt, and the salt bath and die raised together to the quenching temperature.

M. H. MEDWEDEFF: You heat it to about 1440 degrees Fahr. before you put it in the salt bath?

SAM TOUR: No, we heat it to about 1100 degrees Fahr. At 1400 degrees Fahr. you might as well go ahead and treat it without a salt bath. You scale it at 1400 degrees Fahr.

M. H. MEDWEDEFF: If you heat it under a reducing atmosphere, which can be done in a gas furnace, you would avoid scaling.

CHAIRMAN d'ARCAMBAL: What happens when you take a piece at 1400 degrees Fahr. through the air to transfer it to the salt bath?

M. H. MEDWEDEFF: If you put a little salt in your furnace, a film forms on your die, and then you can quench it without fear of scaling.

CHAIRMAN d'ARCAMBAL: Put salt in the furnace you mean?

M. H. MEDWEDEFF: Spread it on the die before you put it into the furnace. That forms a film, and you can quench it without any scaling.

SAM TOUR: You get a mottled surface on your die every time you do it. I have yet to find a film formed perfectly in that way.

CHAIRMAN d'ARCAMBAL: You know when a person gets a good, clean tool out of the furnace, they think they have a fine hardening job. For instance, with tools that are hardened in the electric furnace, or the gas-fired furnace, with too great an excess of gas, you obtain a tool that is gray in color and absolutely clean, but you put a file on it and you have quite a deep, soft skin. Just because your tool comes out clean is no reason why you have a good tool, because decarburization is formed with too great an excess of fuel.

L. A. LANNING: As regards the length of life of the pot, would that average about 500 hours? That is, your alloy pots? Has that been the experience?

SAM TOUR: You cannot lay down any statement like that as to the length of life of the pot. That varies with the temperature, it varies with the size of the pot, it varies with the kind of furnace used, how it is fired, whether oil or gas, etc. It is difficult to say that the pot will last so many hours. The particular furnace I was using, taking a pot which will hold about 500 pounds of salt, operated under conditions with salt getting into the furnace chamber, and a few other things bad for the pot, 500 hours was as long as they would last.

CHAIRMAN d'ARCAMBAL: What kind of a pot?

SAM TOUR: A chromium alloy heat resisting pot.

L. A. LANNING: We operated two such pots and one of them ran a little bit over one thousand hours, and the other one has run over a thousand hours now. I do not know how long it is going to last, that is, with a temperature of 1500 or 1550 degrees Fahr.

SAM TOUR: A pressed steel pot will give much better service than the chromium alloy pot. If the chromium alloy pot lasts 1000 hours, in the same furnace, under the same conditions a pressed steel pot ought

to last a length of time which will more than pay for itself. It will probably last 500 hours, and will cost a lot less than one-half as much.

MR. TURNER: I would like to ask whether it is possible to drive off the moisture in salt below the melting point of the salt, say 400 or 425 degrees Fahr., whether it is necessary to melt the salt to drive off the moisture.

SAM TOUR: I would have to be more of a chemist than I am to answer that in regard to all the salts. For instance, borax has several stages. Take calcium chloride, and so far as I know we have been able to get the moisture off very nicely without ever getting it molten. Some salts go through a lot of reactions in losing all their moisture. Our usual practice is to melt a salt in order to make sure that the salt is perfectly dry.

INVESTIGATION OF THE TREATMENT OF STEEL FOR PERMANENT MAGNETS

By Ralph L. Dowdell

Abstract

This paper deals with various treatments of tungsten, chromium, cobalt-chrome and miscellaneous magnet steels in order to give them the greatest permanence. A simple but accurate testing apparatus for bar magnets is explained. A new type of coercive force called open circuit coercive force is compared with the usual coercive force (closed circuit).

Magnetic saturation curves are given for these steels. The effect of drawing temperature on the remanent induction and coercive force of hardened bar magnets is shown. Magnets with a high coercive force have a smaller per cent loss of remanent induction than magnets with a low coercive force when subjected to impact forces.

Natural and artificial aging curves are given for 17 different treatments. Results indicate that magnets should be hardened so as to have the highest scleroscope hardness possible without cracking. The magnets giving the greatest permanence had a treatment consisting of a draw at 100 degrees Cent. (212 degrees Fahr.) for about 10 hours, followed by magnetizing. They were then quenched 10 times in ice water from boiling water.

Introduction

THE purpose of this investigation was to study the relation of chemical composition, heat treatment and microstructure, to the magnetic properties of different steels for permanent magnets. A limited amount of research has been done on the open circuit testing of permanent magnets and most of these results have been measured in arbitrary units that cannot be converted into centimeter-gram-seconds (c.g.s.) units.

As most permanent magnets operate under open circuit conditions, it is probably of more importance to measure the remanent induction than the residual induction in testing. By open circuit conditions is meant that the poles of the magnet are separated

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by an air gap, while in the closed circuit condition there is no air gap present. By remanent induction (B_{rem}) is meant the magnetic induction measured in terms of lines of force per square centimeter threading through the magnet (in open circuit testing) after the magnetizing force is cut off. The centimeter-gram-seconds electromagnetic unit of measurement is the *gauss*. By residual induction (B_r) is meant the magnetic induction measured in terms of lines of force per square centimeter threading through the magnet (in closed circuit testing) after the magnetizing force has been reduced gradually to zero. Its centimeter-gram-seconds electromagnetic unit of measurement is also the *gauss*.

The magnetizing field strength (H) in the solenoid about the magnet is measured in terms of the number of lines of force threading through the solenoid per square centimeter. Its centimeter-gram-seconds electromagnetic unit is called the *gilbert* but frequently the *gauss* is used.

Another property usually determined in magnetic testing is called *coercive force*. The coercive force of a magnet is the negative value of magnetizing force required to reduce its induction to zero. It is usually true that magnets with high coercive forces resist shock better than ones with low coercive force. A good permanent magnet then should have a B_{rem} and coercive force as high as possible and remain constant over a period of time, when subjected to shock and the action of demagnetizing forces.

Magnet Steels Used in the Investigation

The steels investigated consisted of most of the different classes of permanent magnet steels used in this country. In addition to steels which are generally used for permanent magnets, nickel steels, chrome-nickel steels, chrome-vanadium steels, chrome-molybdenum steels, and carbon steels of different carbon contents, have been included for theoretical considerations. The chemical compositions of the various steels used in this investigation are shown in Table I.

Thermal Analysis

The critical points of all the steels tested were determined by thermal analysis with a Weston potentiometer for indicating the electromotive force of the thermocouple. A noble metal couple

which had previously been checked against the United States Bureau of Standards freezing points of pure metals, was generally used. The steels analyzed by the thermal method were in the annealed state, of a size 3/4 inch long by 1/2 inch in diameter,

Table I

Chemical Analyses of Steels Used in Investigation

No.	C	Mn	Si	P	S	Cr	W	Ni	Co	V	Mo
					Tungsten Steels						
68	.53	.36	.40	.017	.007	.57	5.17	....	....	....	....
69	.67	.56	.29	.013	.018	.18	5.07	....	....	....	....
73	.67	.61	.31	.014	.007	.20	5.43	....	....	....	....
74	.61	.38	.25	.022	.027	none	5.31	....	....	....	....
88	.76	.61	.56	.022	.011	.41	5.08	....	....	....	....
					Chromium Steels						
67	.72	.56	.35	.011	.014	2.17	0.19	....	....	....	....
70	.97	.74	.33	.031	.005	2.87	....	....	....	....	....
71	.80	.56	.30	.013	.002	2.16	....	....	....	....	....
					Carbon Steels						
51	.70	.63	.17	.028	.033	....	....	....	....	....	....
54	.74	.57	.20	.016	.007	....	....	....	....	....	....
75	.98	.65	.11	.033	.018	....	....	....	....	....	....
76	1.18	.56	.11	.020	.021	....	....	....	....	....	....
104	.76	.84	.29	.015	.025	....	....	....	....	....	....
105	.76	.52	.28	....	.011	....	....	....	....	....	....
106	.54	1.28	.27	.021	.032	....	....	....	....	....	....
					Miscellaneous and Special Steels						
15	.35	.45	.23	.019	.008	....	....	5.03	....	....	....
18	.11	.22	.10	.021	.001	15.70	....	....	....	....	....
37	.41	.85	.14	.013	.024	.89	....	2.59	....	....	....
81	.43	.63	.26	.013	.012	....	....	3.54	....	....	....
84	.39	.90	.24	.020	Tr	.51	....	1.37	....	....	....
97	.34	.40	.11	.002	.034	.77	....	....	....	....	.72
98	.50	.70	.16	.002	.021	1.05	....	....	....	.22	....
99	.86	.13	.16	.015	.041	9.31	....	....	13.66	....	1.24

with a hole 7/16 inch for inserting the thermocouple. The time intervals used in plotting the inverse rate curves were measured by two stop watches[1] mounted in a wooden block so that one operator could make a thermal analysis with ease and know the rate of temperature change of the specimen at all times.

Inverse rate curves on some of the steels are given on Figs. 1 and 2. The rate of heating or cooling was about 4 degrees Cent. per minute. It must be remembered that the rate of heating or cooling largely determines the position of the critical points. Stainless steel No. 18 shows the Ac_2 below the $Ac_{1\cdot3}$ and the $Ar_{3\cdot1}$ above the Ar_2. This is due to the fact that chromium raises

1. Merica, *Bulletin A. I. M. E.*, 151, 1021 (1919).

the solid solution transformation while the magnetic transformation remains about the same as in carbon steels.

Magnet Test Bars

It is generally accepted, and shown in Fig. 10, that a good permanent magnet should have a magnetic ratio between about 25 and 30 in order to store a large number of lines of force within

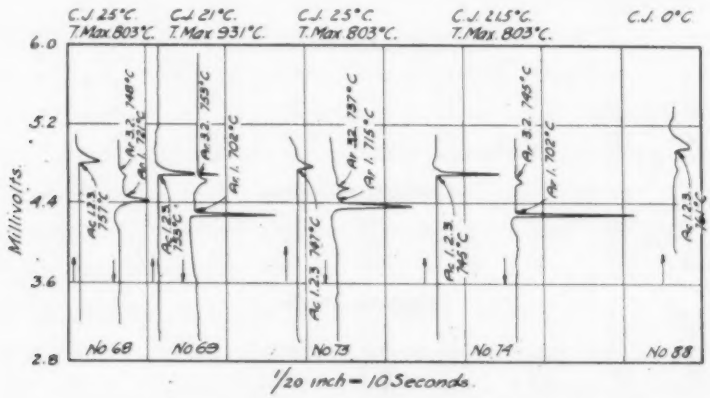


Fig. 1—Inverse Rate Curves Showing the Critical Points of Some of the Steels Tested.

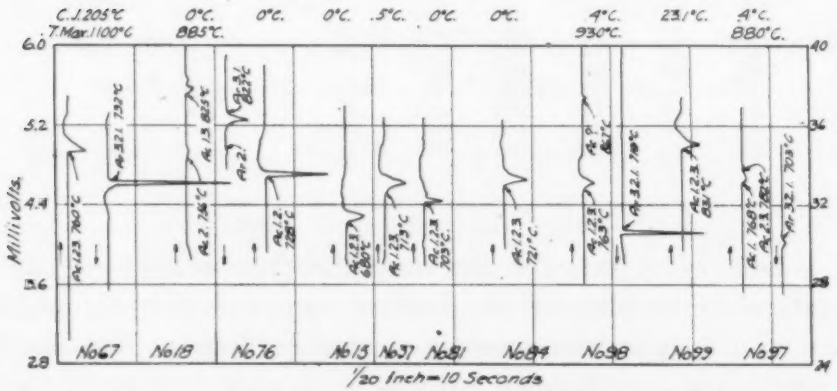


Fig. 2—Inverse Rate Curves Showing the Critical Points of Some of the Steels Tested.

it. The magnetic ratio (length/diameter) chosen for the test bars, unless otherwise specified, was 26.7, the bars being 10 inches long by 3/8 inch in diameter. This was considered the largest ratio that could be successfully heat treated and tested. The bars were machined from 3/4-inch diameter annealed stock and given a No. 1 emery cloth finish. In the machining operation a small

Table II

Annealing and Normalizing of Magnet Steels Investigated

Steel No.	Ac_3 Degrees Cent.	Held at Degrees Cent. for 1 hour	Method of cooling	Average Scleroscope reading	Remarks
			Tungsten Steels		
68	760	790	Furnace	41.8	
69	760	790	Furnace	45.0	
73	750	790	Furnace	43.2	
74	750	790	Furnace	44.4	
88	761	850	Furnace	40.0	Received in hardened state.
			Chromium Steels		
67	765	790	Furnace	40.2	
70	765	790	Furnace	41.2	
71	765	790	Furnace	40.0	
			Carbon Steels		
51	750	750	Furnace	40.4	
54	735	790	Furnace	36.4	
75	760Acm	800	Air	49.0	
76	800Acm	790	Furnace	....	
104	745	790	Air	34.0	
105	745	790	Air	48.0	
106	775	790	Air	40.0	
			Miscellaneous and Special Steels		
15	680	750	Furnace	37.0	
18	825	850	Furnace	36.4	
37	715	750	Furnace	40.5	
81	705	750	Furnace	33.8	
84	721	750	Furnace	41.0	
97	785	800	Furnace	40.0	
98	763	900	Furnace	....	Above Ac?
99	840	900	Furnace	52.0	

Table III

Effect of Intensity of Magnetizing Field on the Remanent Induction of Permanent Magnets

Steel and Bar No.	Open Circuit Coercive Force	*Brem* in Gausses for Cumulative Values of H											
		H 25	H 50	H 75	H 100	H 150	H 200	H 250	H 300	H 350	H 400	H 500	H 600
74–1	57.3	384	2075	3935	5687	7265	7720	7850	8050	8050	8129	8129	
74–2	65.0	269	1615	3510	5660	7730	8400	8580	8760	8760	8790	8805	
74–3	72.2	131	657	2670	5560	8150	8940	9200	9370	9420	9459	9459	
74–4	63.1	176	1230	3510	5355	7240	7720	7950	8000	8040	8082	8082	
68–1	58.2	211	1370	....	6815	8448	8890	9117	9117	9117	9158	9158	
70–1	65.0	153	919	3765	6130	8140	8750	9020	9120	9150	9192	9192	
76–1	81.0	44	396	1580	3700	5767	6565	6872	7048	7135	7174	7174	
54–1	69.3	131	962	2620	4680	6565	7088	7310	7480	7500	7529	7529	
51–1	65.0	111	935	2980	5515	7170	7695	7880	8020	8056	8056	8056	
81–1	43.5	625	2415	3800	4560	5185	5410	5455	5455	5455	5455	5455	
73–1	54.0	715	2100	3620	4830	5900	6260	6348	6385	6385	6465	6481	
67–1	56.1	112	1390	4570	6950	8560	9060	9100	9197	9197	9197	9197	
84–1	36.0	808	2425	....	4267	4717	4807	4807	4807	4850	4898	4898	
71–1	56.6	133	1370	4465	6920	8520	8970	9100	9150	9150	9195	9243	
69–1	63.0	66	1020	3865	6660	8570	9150	9380	9420	9559	9559	9559	
15–1	47.0	201	2100	4371	5412	6480	6843	6925	7018	7018	7018	7018	
37–1	44.5	311	2400	4800	6091	7105	7375	7420	7511	7511	7511	7511	
18–1	58.8	183	1147	3210	4540	5550	5970	6100	6200	6200	6219	6219	
18–2	55.0	257	1450	3415	4625	5520	5805	5900	5900	5900	5925	5945	
88–2	66.0	178	932	3555	6525	8750	9380	9580	9680	9772	9800	9822	
97–1	44.5	364	2160	4367	5640	6420	6662	6790	6790	6790	6790	6790	
98–1	51.0	302	2093	4520	6285	7500	7775	7968	7968	7968	7968	7968	
99–1	122.8	23	225	542	1330	4420	6225	7085	7530	7725	7800	7953	7955

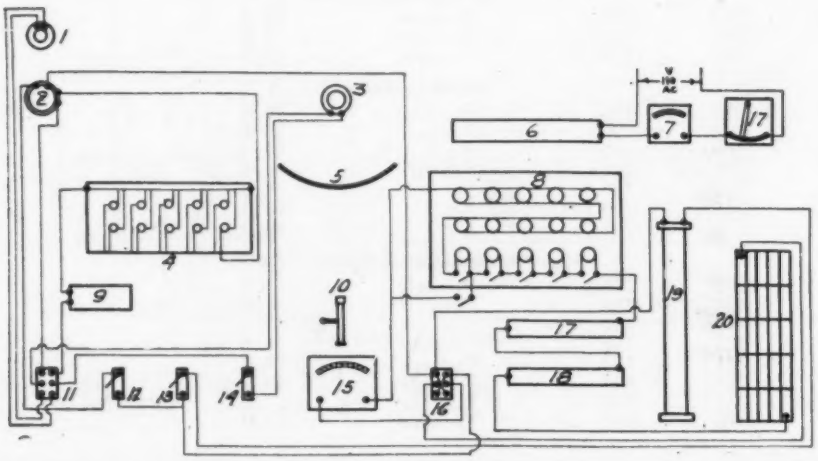
Brem in low by factor 1.137

coupon 1/4 inch long was made by notching the bar 1/8 inch wide and 1/8 inch deep in the direction of its diameter. This coupon was broken off after heat treatment and used for microscopic investigation.

Heat Treatment and Microstructure

Annealing

The materials tested were in most cases furnished as 3/4-inch round bars. They were either annealed or normalized in order to



1	Test Coil for Coercive Force.	11	Double Throw Switch.
2	Mutual Inductance.	12	Knife Switch.
3	Ballistie Galvanometer.	13	Knife Switch.
4	Test Coils for Magnetic Flux.	14	Knife Switch.
5	Galvanometer Scale.	15	D. C. Ampere-Meter.
6	Solenoid for Demagnetizing.	16	Reversing Switch.
7	A. C. Ampere-Meter.	17	Slide-Wire Resistance
8	Lamp-Bank Resistance.	18	Slide-Wire Resistance
9	1000 Ohms Resistance.	19	Magnetizing Solenoid.
10	Telescope.	20	Storage Batteries or 110 V-D.C.

Fig. 3—Wiring Diagram of Apparatus Used in Testing the Magnets.

facilitate machining operations and also to minimize the warpage in subsequent hardening operations. The annealing or normalizing temperatures, the method of cooling, and the scleroscope hardness obtained in this treatment are shown in Table II.

Hardening

The magnet bars were hardened either from a lead pot or a muffle furnace. All of the bars were brought to the hardening temperature in about one-half an hour, held at the hardening tem-

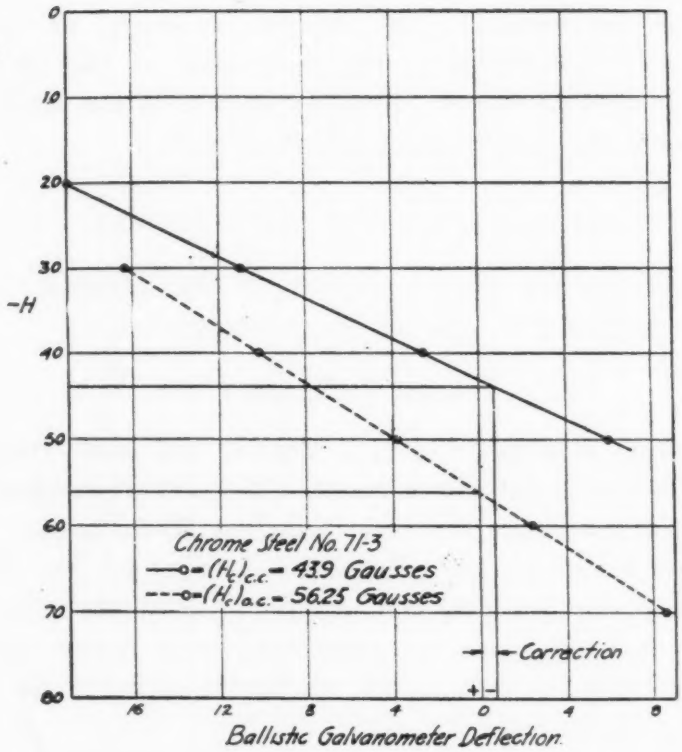


Fig. 4—Diagram Showing Method of Finding Coercive Force, Curve of Chrome Steel 71-3.

perature for 15 minutes, and quenched vertically in tap water maintained at a temperature between 5 and 10 degrees Cent. The hardening temperatures of the different bars can be found in the accompanying tables.

Drawing

In drawing the demagnetized bars, little difficulty was encountered, but in drawing magnetized bars it was essential to keep them away from ferromagnetic substances. These latter draws were usually performed in a gas-fired copper drying oven (up to 200 degrees Cent.) or in an automatically controlled electric drying oven built of brass and transite board. The higher temperature draws were carried on in a gas muffle furnace. The time and temperature of drawing the bars in the different series can be found in the accompanying tables.

Microstructure

The microstructure of the annealed steels was usually a fine

granular pearlite. The structure of the hardened steels was the characteristic martensite. The needle structure of martensite becomes much less distinct as the percentage of the alloying elements of the steel increases. In other words, as the steel becomes more austenitic the needles gradually disappear.

Apparatus for Magnetic Testing

Fig. 3 shows the wiring diagram of the apparatus used for testing the magnet bars during the investigation.

Mutual Inductance

The mutual inductance (No. 2, Fig. 3) was made from a fiber tube having a 4-inch outside diameter, a 3 1/2-inch inside diameter, and 31 1/5 inches long. A screw thread of 20 turns per inch was cut the entire length of the tube and 624 turns of No. 18 double cotton covered copper wire was wound in a single layer on the tube. The wire was further protected by a heavy coating of shellac on the finished coil. This winding constituted the primary of the mutual inductance.

The field strength (H=gausses) of a solenoid in centimeter-gram-seconds units is given by the equation:

$$H = \frac{4\pi N I}{10 L}$$

when I is in amperes and L is in centimeters. The primary winding was put on in its particular way so that there would be eight turns per centimeter in order to simplify calculations. To obtain the field strength with such a winding it is only necessary to multiply the current in amperes in the solenoid by 10 which gives the flux within the solenoid,[2] or $H = 10 I$.

Around the middle of the primary winding was wound 785 turns of No. 30 double cotton covered copper wire of 100 turns per layer, constituting the secondary winding of the mutual inductance.

Movable Test Coil

A movable test coil (No. 1, Fig. 3) was made by winding

2. Magnetic testing, U. S. Bureau of Standards, Circular No. 17, 1916.

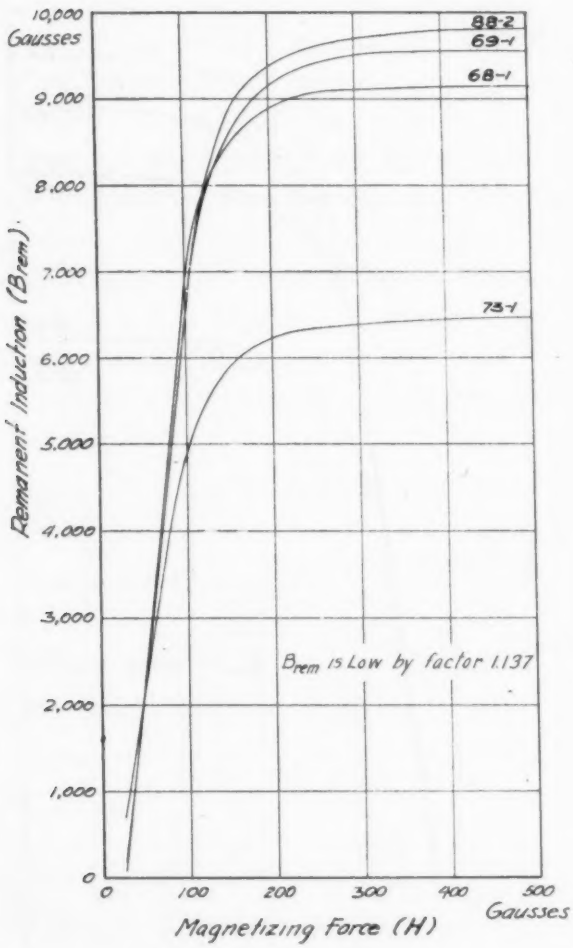


Fig. 5—Saturation Curves Showing the Variation of Remanent Induction (*Brem*) with Magnetizing Force (H) for Tungsten Steels. Steels 88-2, 69-1, 68-1 and 73-1 are Represented.

Table IV

Effect of the Surface Finish of Permanent Magnets on Their Retentivity

Steel 105 Normalized

Bar No.	Surface Finish	*Brem* Feb. 17, 1923	*Brem* June 25, 1923	Per Cent Loss of *Brem*
1	Rough turned	2800	2475	11.6
2	Smooth turned and polished with No. 1½ emery paper	2688	2366	11.97
3	Polished with No. 1 emery cloth	2765	2394	13.42
4	Polished with No. 1 Hubert paper	2794	2444	12.52
5	Rouge polished	2755	2372	13.9

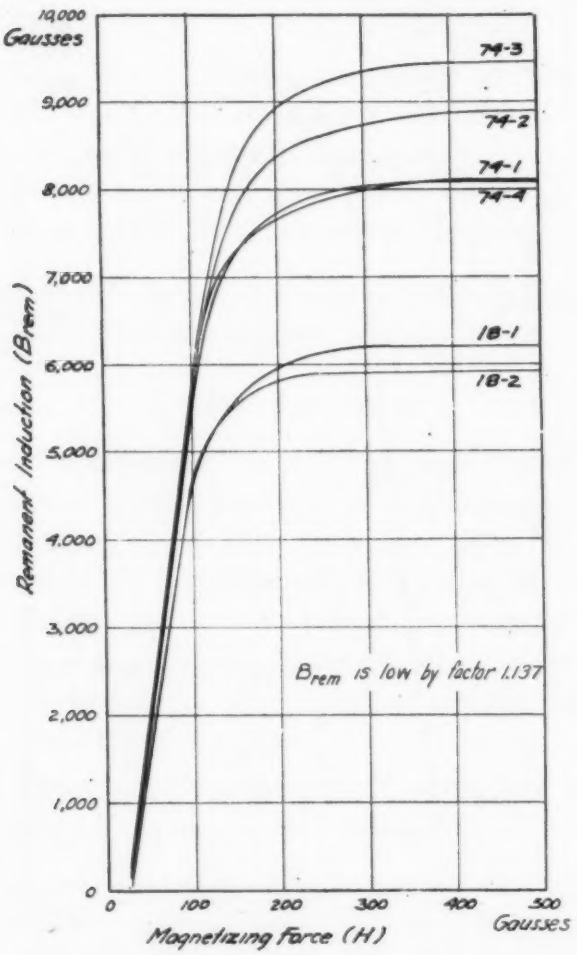


Fig. 6—Saturation Curves Showing the Variation of Remanent Induction (Brem) with Magnetizing Force (H) for Tungsten and High Chromium Steels. Steels 74-1, 74-2, 74-3, 74,4, 18-1 and 18-2 are Represented.

100 turns of No. 30 enameled copper wire on a wooden spool. A circular piece of wood was glued to the bottom of the spool so that it would act as a guide in slipping in and out of the fiber tube of the mutual inductance in the coercive force determinations.[3]

Test Coil Box Used to Measure Magnetic Flux B_{rem}

Apparatus (No. 4, Fig. 3) was made by taking ten high grade glass tubes with 1/16-inch walls, 5/8-inch outside diameter and 10 1/2 inches long. Around the middle of these ten tubes

3. Mme. Curie, Magnetic properties of tempered steels, *The Metallographist*, 1, 229, 1898.

were wound 1, 2, 5, 10, 20, 40, 50, 60, 80, and 100 turns, respectively, of No. 60 enameled copper wire with the leads connected to individual taps so that any one of the tubes could be put into the circuit for the flux measurements. The windings were held in place on the glass rods by rubber cement which when dried made practically a rubber insulation. Rubber stoppers were cut so that they would slip over the ends of these tubes, acting as spreaders. These tubes were then mounted in vertical positions in a wooden box. Horizontal slides were made at the bottom of each tube so that the operator could trip the magnet which had been placed within the tube with the coil at its center.

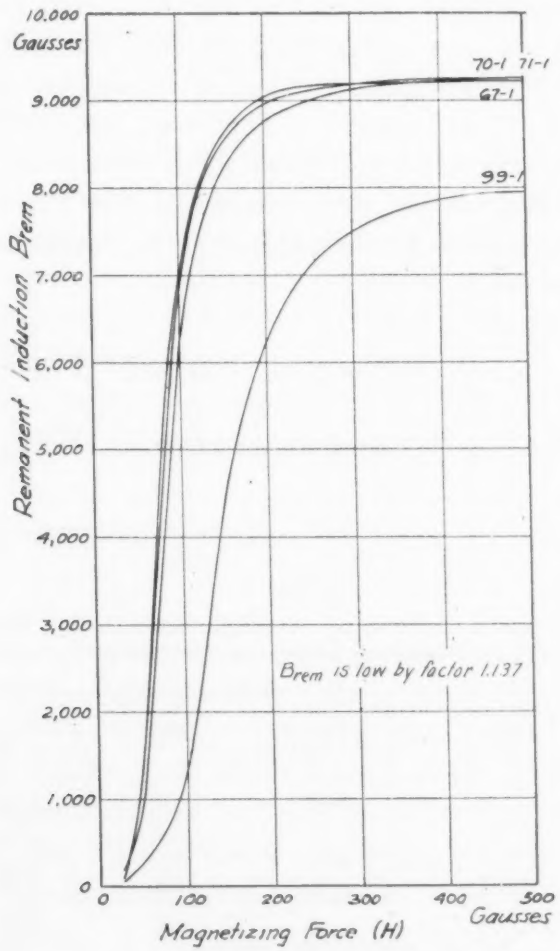


Fig. 7—Saturation Curves Showing the Variation of Remanent Induction (*Brem*) with Magnetizing Force (H) for Chromium Steels. Steels 70-1, 71-1, 67-1 and 99-1 are Represented.

On tripping, the magnet fell through the test coil onto three heavy layers of felt which took up the impact largely, thus protecting the magnet against a loss of flux.

Demagnetizing Solenoid

The demagnetizing solenoid (No. 6, Fig. 3) consisted of 2000 turns of No. 15 double cotton covered copper wire wound on a brass spool.

Ampere-Meter

The ampere-meter (No. 15, Fig. 3) used to measure the field strength of the different parts of the apparatus was a direct current Weston ampere-meter of 10 ampere capacity graduated in tenths of an ampere. This was standardized against a larger meter which was later found to be incorrect by the physics and electrical engineering departments of the University of Minnesota. This accounts for the factor 1.137 found on some of the tables and graphs.

Magnetizing Solenoid

The magnetizing solenoid (No. 19, Fig. 3) was made from a

Table V

Influence of D.C. and A.C. (60 cycle) Magnetic Fields During Quenching on the Remanent Induction of Magnets

Heat No.	Quenching Temp. Degrees Cent.	Number Bars in test	Average B_{rem} for Different Fields: A. C. Field 500 Gauss During Quench	No Field	D. C. Field 500 Gauss During Quench	Carbon Per Cent
1	900	15	6680	6650	6675	.76
2	900	15	....	6750	6589	.76
3	900	6	.....	4845	4790	.76
4	900	5	6040	5925	.....	.76
5	900	12	.....	5762	5548	.76
6	900	5	2253	2150	.....	.36
7	900	4	.....	2240	2148	.37
8	900	13	7050	6880	6930	.76

Note: The bars were quenched in water between 5.5 and 10 degrees Cent. under the influence of the different magnetic fields after which they were all magnetized at 500 gausses (D.C.) and tested. The steels used were straight carbon steels.

fiber tube having an outside diameter of 1 inch, a 3/4-inch inside diameter, and a length of 23.6 inches (60 centimeters). On this tube was closely wound 10 layers of No. 17 enameled copper wire making 482 turns per layer or practically 8 turns per centimeter. The magnetic field in gausses in this solenoid was then $H = 100\,I$, on account of there being 10 layers.

An infinitely long solenoid would have the same field strength at its center that it would have at either end. An equation for the field strength for any point along the center line of the solenoid is given as[4]

$$H = \frac{2\pi N I (\cos a + \cos a')}{10 L}$$

H = field strength in gausses
N = total number of turns
I = amperes
a = angle subtended between center line of solenoid at the point where the field is to be determined, and a line from that point to the inside circumference of the end of the solenoid winding
a' = The angle subtended at the opposite end of the solenoid.

If the point is in the center of the solenoid the $(\cos a + \cos a') = 2 \cos a$ with the cos of a approaching 1 at infinity or making the equation

$$H = \frac{4\pi N I}{10 L}$$

In calculating the required length of the magnetizing solenoid so that at a point 5 inches from the center there would be a negligible error (the magnet being 10 inches long, or 5 inches on each side of the center), it was found that the field was 0.05 per cent less at the end of the bar than at the center for a solenoid 60 centimeters long. The fields at the center and ends of the magnet can therefore be considered the same.

Hammer Machine

A machine was built of wood for the hammering of mag-

4. Zelney Laboratory Manual of Physics, 1920.

Table VI

Effect of Drawing Temperature on Open Circuit Coercive Force and Remanent Induction of Permanent Magnets

Cumulative Drawing Temperatures, Degrees Centigrade.

Bar No.	Quench Temp.	Sclero-scope hard-ness	20		50		100		200		260		300		400		500		600		700	
			-Hc	Brem	-Hc	Brem	-Hc	Brem	-Hc	Brem	-Hc	Brem	-Hc	Brem	-Hc	Brem	-Hc	Brem	-Hc	Brem	-Hc	Brem
18–1	835	67.8	58.8	6219	58.8	6242	58.3	6320	57.0	6242	58.2	6335	57.7	6420	56.7	6506	52.5	6490	16.3	3469	14.3	3323
18–2	835	67.0	55.0	5944	55.0	5992	55.0	6060	53.4	5944	53.2	5992	53.4	5992	51.5	6067	49.0	6060	15.5	3435	14.0	3100
88–2	771	....	66.0	9822	65.5	9867	65.5	9770	51.8	9280	37.8	7115	33.4	6040	30.7	5850	24.9	6060	21.0	5240	17.7	4305
70–2	775	90.4	64.0	9239	64.2	9239	63.4	9315	54.8	8920	41.4	7150	37.5	6140	36.7	6155	31.7	5940	27.9	5827	17.25	4325
69–2	770	88.6	63.4	9428	63.5	9517	62.5	9620	51.0	8750	34.0	6090	32.2	5685	26.4	5475	23.0	5690	20.75	5310	16.25	3975
71–2	775	91.6	56.7	9271	56.7	9271	56.4	9390	47.2	8650	36.1	6440	34.5	6080	29.5	5701	22.1	5285	18.3	4735	15.65	4000
73–2	760	69.9	56.5	7691	56.3	7691	55.7	7760	45.0	7065	32.1	5400	30.0	5105	26.9	4952	23.7	4815	20.25	4810	17.3	4050
67–2	775	86.0	56.7	9284	56.7	9284	55.6	9340	47.2	8630	35.8	6270	34.9	5965	31.8	5708	23.3	5110	19.0	4770	16.65	4015
54–2	745	90.0	70.6	7511	71.0	7511	68.9	7530	55.0	7200	35.5	5335	31.5	4935	27.7	4882	30.2	5620	21.75	4080	16.2	2808
15–2	690	72.4	47.9	6661	47.9	6639	46.0	6590	38.8	5820	27.0	4070	26.0	3610	17.0	2913	15.3	3140	11.5	2625	20.8	2995
84–2	731	65.6	40.1	5422	40.2	5467	39.2	5700	35.5	5020	25.5	3660	24.0	3420	22.5	3285	15.5	2960	12.0	2640	9.1	1910
51–2	760	88.2	66.7	7869	66.3	7958	64.6	7985	51.5	7400	33.0	5040	29.0	4637	24.0	4611	26.6	5360	20.0	4460	15.2	3435
76–2	810	86.2	80.5	7073	76.7	7073	76.7	7170	61.0	7310	37.7	5565	34.8	5255	32.0	5371	32.5	6025	24.5	4505	19.0	3160
81–2	715	74.0	45.2	7238	45.0	7238	43.0	7110	36.7	6075	26.6	4020	26.0	3790	22.0	3429	15.6	3495	12.5	499	15.3	2740
37–2	725	73.0	44.0	7417	43.6	7462	....	.....	39.0	6740	30.7	4780	30.7	4685	26.5	4208	17.0	3920	15.0	3661	14.0	3180

Note: These bars were drawn at the above temperatures for one hour in an electric muffle furnace and air cooled from draw. After this air cooling the bars were all magnetized at 500 gausses and tested immediately. After this testing the magnets were demagnetized in an A.C. solenoid and drawn at the next higher temperature, repeating the above operation. *Brem* is low by factor 1.137.

Table VII

Effect of Drawing Temperature on the Remanent Induction of Permanent Magnets While in the Magnetic State

Bar No.	Quench Temp.	Sclero-scope Hardness	-Hc 20 Degrees Centigrade Open Circuit	Closed Circuit	Cumulative Drawing Temperatures, Degrees Centigrade — Brem 20	50	75	100	125	150	200	250	300	400	500	600	700	800
69–3	770	88.1	62.5	49.3	9283	9230	9200	9125	8900	8725	8050	6110	5420	4700	4270	3400	2270	108
67–4	775	86.0	54.7	43.2	8675	8590	8535	8535	8400	8085	7590	6085	5575	4940	4005	3055	1830	—21
81–3	715	69.1	40.75	27.7	5958	5825	5825	5760	5570	5330	4830	3290	2885	2455	2045	1220	305	—65
84–3	731	61.0	41.7	28.9	5930	5789	5740	5710	5550	5400	4900	3550	3230	2918	2485	1855	655	—43
70–3	775	82.0	62.8	49.8	9020	8930	8930	8850	8600	8520	8040	6250	5775	5250	4350	3485	2425	11
88–1	771	76.0	65.3	52.3	9675	9650	9630	9530	9370	9255	8485	6320	5770	4985	4048	3350	2595	—22
73–3	760	68.5	59.5	44.2	7375	7320	7280	7180	6995	6860	6360	5095	4635	4120	3765	3075	1910	—11
51–3	760	84.1	63.9	47.9	7875	7785	7750	7648	7230	7000	6270	4335	3510	3325	3150	1779	1415	—117
76–3	810	84.4	78.6	60.2	6872	6872	6865	6720	6580	6450	5665	4380	3895	3750	3115	2055	368	—75
15–3	690	73.8	45.5	31.7	6475	6410	6400	6300	6185	5997	5250	3450	3060	2300	1980	301	215	—75
37–3	725	77.0	43.4	31.0	7050	6995	6950	6910	6720	6575	5920	4450	4250	3692	2000	1800	615	—22
54–3	745	85.6	67.4	49.5	6930	6930	6875	6725	6625	6430	5465	4275	3779	3580	2895	1680	660	—21
	Date of Test.....		22	22	24	24	24	October, 1921 25	26	27	28	28	29	31	31	November, 1921 1	1	1

Note: These bars were magnetized at 500 gausses and coupled in pairs by wrought iron yokes (¾-inch square stock) with ⅜-inch holes drilled ½-inch deep and 1¾ inches between centers. The yokes were previously magnetized and were always applied to the same ends of the same bars throughout the experiment. Unlike polarities of the magnets were coupled together so that each pair formed a complete magnetic circuit.

The bars were drawn at temperatures above 300 degrees Cent. (570 degrees Fahr.) in a gas muffle furnace for one hour with the yokes on; then air cooled and tested. *Brem* is low by factor 1.137.

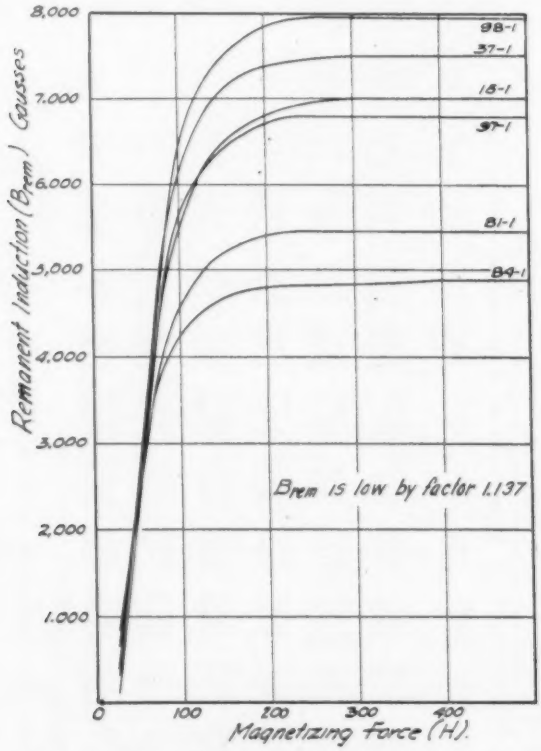


Fig. 8—Saturation Curves Showing the Variation of Remanent Induction (*Brem*) with Magnetizing Force (H) for Nickel and Chrome-Nickel Steels. Steels 37-1, 15-1, 81-1, 84-1, 98-1 and 97-1 are Represented.

netized bars in order to determine their stability to shock. It consisted of brass anvil blocks weighing 1 pound each, in which three magnetized bars were placed at one time, 18 inches apart, vertically with their actual north poles up. They were struck with brass hammers weighing 1 pound each, which were tripped by a camshaft from a head of 1 foot, giving 21 blows per minute.

Procedure in Testing Magnets

Electrical Energy

The electrical energy used for magnetizing was obtained, in the earlier part of the work, from a number of storage batteries connected in series, but later from a 15-kilowatt motor-generator set developing direct current at 110 volts. The latter, however, was found to be more satisfactory than a storage battery arrangement but not as constant.

Table VIII

Relation of Per Cent Loss of Remanent Induction Under Impact to the Coercive Force for Various Steels

Steel No.	Scleroscope hardness	Brem			Coercive Force	
		Before Hammering	After Hammering	Per Cent Loss	Open Circuit	Closed
Tungsten Steels						
73	85	9600	9230	3.86	70.4	56.0
69	45	2775	67	97.5	14.1	10.7
73	93	9350	9030	3.42	78.2	61.4
69	96	9530	9070	4.82	67.5	53.2
73	73	5180	2820	45.5	25.0	20.6
69	70	5480	2860	47.8	22.8	18.7
69	42	5230	1535	70.6	15.6	13.8
73	51	5290	1340	74.5	19.5	16.4
Chromium Steels						
70	41	4690	2615	44.2	30.1	22.7
70	94	9420	9035	4.1	69.7	57.2
70	74	5870	3160	46.2	27.8	20.8
70	50	4575	1385	69.7	18.75	15.7
Chrome-Molybdenum Steels						
97	40	1650	114	93.0	10.7	7.0
97	75	7000	5950	15.0	45.2	32.0
97	64	3760	1420	62.2	22.0	14.3
97	42	2890	139	95.1	11.7	9.8
Cobalt-Chrome Steel						
99	52	5880	87	98.5	26.0	21.1
99	60	7415	4460	39.9	52.7	39.4
99	55	7180	4195	41.5	48.0	35.5
99	52	4950	45	99.0	22.3	17.5
99	86	8025	7685	4.23	137.3	115.4
Carbon Steels						
106	86	7200	6525	9.4	65.4	45.4
106	40	2630	723	72.5	15.2	9.8
75	49	2630	1455	44.7	31.0	20.1
Mild steel (C .36)	35	1617	437	73.0	12.2	9.5
75	55	3860	2760	28.5	31.5	20.1

Note: The heat treatments of the above steels were varied in order to produce magnets of different coercive forces.
Each bar was hammered with 945 blows of 1 foot-pound over a period of 45 minutes.

Calibration of Ballistic Galvanometer

The ballistic galvanometer (period = 10 seconds) was calibrated about every 1/2 hour during testing. One ampere was broken on the primary of the mutual inductance and the secondary deflection noted.

Determination of Remanent Induction

The bars tested were all magnetized and reversed 10 times before testing, after which they were tested for remanent induction[5] by dropping them through the 100-turn test coil (No. 4, Fig. 3) and noting the deflection of the ballistic galvanometer.

5. Smith, Theory and Practice of Electrical Measurements, Purdue University, 1909.

In the derivation of the formula, it is assumed without proof that a unit magnet pole has 4π lines of force proceeding from it, the surface of a sphere being 4π. The strength of a magnetic field is then equal to $4\pi N I$ in centimeter-gram-seconds units or dynes.

Now on the mutual inductance,

Let N = number of turns per centimeter
S = total number of turns on secondary
r = radius of secondary in centimeters
A = area of cross section of secondary in square centimeters
Q = coulombs = quantity of electricity transferred by a current of 1 ampere per second.

The magnetic flux ($\emptyset$) through the secondary of the mutual inductance is

$$\emptyset = FA \text{ or force times the area.}$$

$$\emptyset = FA = 4\pi N I A = 4\pi^2 N r^2 I$$

The number of linkings $N = \emptyset S = 4\pi^2 r^2 I S$

$$M = \frac{N}{I} \text{ or } N = M I$$

The value of the current flowing through a resistance R under an electromotive force is given by Ohms law,

$$I = \frac{E}{R}, \quad (a)$$

Remembering that the current $I = \frac{dQ}{dt}$ (b)

and that $E = \frac{dN}{dt}$ (c)

Now combining (a), (b) and (c),

$$\frac{dQ}{dt} = \frac{dN}{dt} = Q = \frac{N}{R}$$

$$\frac{}{R}$$

$$Q = \frac{N}{R} = \frac{M\,I}{R} = \frac{4\pi^2\,N\,r^2\,S\,I}{R} \text{ in c.g.s. units.}$$

However, in practice I is in amperes and R is in ohms.

1 ampere $= 10^{-1}$ in c.g.s. units.
1 ohm $= 10^9$ c.g.s. units.

When the magnet is dropped in the test coil giving the deflection d_1, we have

$$\text{Equation (a), } Q_1 = \frac{N}{R\,10^8} = \frac{B_{rem}\,A\,S'}{R\,10^8} \text{ coulombs} = G\,d_1$$

N = total number of linkings
B = the induction density
A = the cross section of the bar in square centimeters
S′ = number of wire turns on test coil
R = total secondary circuit resistance.

When the primary of the mutual inductance is broken we have

$$\text{Equation (b), } Q_2 = \frac{4\pi\,N\,I\,a\,S}{R\,10^9} \text{ coulombs} = G\,d_2.$$

N = number of primary turns per centimeter
a = area of secondary coil
S = total number of turns on secondary coil.

Solving equations (a) and (b) for G and equating we have,

$$\frac{B_{rem}\,A\,S'}{d_1\,R\,10^8} = \frac{4\pi\,N\,I\,a\,S}{d_2\,R\,10^9}$$

Now solving for B_{rem}

$$B_{rem} = \frac{4\pi\,N\,I\,a\,S\,d_1\,R\,10^8}{d_2\,R\,10^9\,A\,S'}$$

Taking out the constant K we have,

$$K = \frac{4\pi\,N\,I\,a\,S}{10\,S'\,d_2} \text{ or galvanometer constant}$$

$$B_{rem} = \frac{K\,d_1}{A}$$

Table IX

Natural Ageing of Permanent Magnets

Treatment No. 1, Magnetized after hardening; stored in vertical position.

Steel & Bar No.	Ac_3 Degrees Cent.	Quench Temp. Degrees Cent.	Sclero-scope Hard-ness	(-Hc) *oe.*	After Hard-ening	When Stored	After 40 days	After 171 days	After 375 days	After 497 days	After 642 days	After 740 days	After 775 days
51–1	750	760	85.2	65.0	9160	9160	8797	8556	8317	7959	7743	7356	7277 Brem
						0	3.96	6.59	9.19	13.1	15.4	19.7	20.5 % Loss
54–1	735	745	86.8	69.3	8560	8560	8200	7902	7635	7305	7108	6690	6604
						0	4.20	7.68	10.8	14.65	16.95	21.8	22.8
76–1	800	810	89.0	81.0	8157	8157	8042	7535	7237	6947	6767	6326	6257
						0	1.41	7.75	11.3	14.85	17.00	22.4	23.3
68–1	760	770	89.2	58.2	10413	10413	10028	9891	9562	9175	8982	8535	8435
						0	3.69	5.0	8.16	11.87	13.75	18.0	19.0
69–1	760	770	92.4	63.0	10868	10868	10568	10460	10079	9664	9500	9061	8970
						0	2.76	3.76	7.25	11.1	12.5	16.6	17.4
73–1	750	760	87.6	54.0	7369	7369	7104	6816	6799	6572	6367	6014	5930
						0	3.60	7.5	8.55	10.8	13.6	18.4	19.5
74–1	750	760	83.8	57.3	9240	9240	8641	8508	8330	7980	7698	7360	7210
						0	6.4	8.05	9.87	13.65	16.75	21.0	22.0
74–2	750	850	88.2	65.0	10011	10011	9530	9420	8891	8777	8507	8096	8010
						0	4.8	5.90	11.2	12.3	14.98	19.1	20.0
74–3	750	950	91.6	72.2	10755	10755	10545	10443	10079	9684	9445	9061	8885
						0	1.95	2.90	6.27	9.95	12.2	15.7	17.4
74–4	750	600*	92.0	63.1	9189	9189	8925	8726	8448	8124	7876	481	7400
						0	2.87	5.05	8.08	11.6	14.3	78.6	19.5
67–1	765	775	88.4	56.1	10456	10456	10114	9704	9250	9068	8846	1402	8300
						0	3.28	7.20	11.5	13.3	15.4	89.6	20.6
70–1	765	775	96.6	65.0	10450	10450	10200	10022	9636	9317	9167	1687	8525
						0	2.38	4.1	7.80	10.8	12.3	86.8	18.4
71–1	765	775	93.8	56.6	10509	10509	10255	10460	9803	9625	9309	1877	8830
						0	2.23	....	6.27	8.42	11.4	85.5	16.0
15–1	680	690	75.8	47.0	7979	7979	7609	7368	7174	6964	6798	1358	6319
						0	4.65	7.65	10.1	12.7	14.81	60.3	20.8
81–1	705	715	70.0	43.3	6202	6202	5820	5664	5452	5298	5160	2835	4795
						0	6.15	8.67	12.1	14.6	16.8	42.0	22.7
84–1	721	731	73.8	36.0	5569	5569	5292	5077	4821	4787	4633	24347	4328
						0	4.96	8.84	13.3	14.0	16.8	21.9	22.3
37–1	715	725	78.0	44.5	8540	8540	8186	7908	7561	7419	7148	6815	6752
						0	4.37	7.4	11.45	13.1	16.3	20.2	21.0
		Average Per Cent Loss.....				0	3.75	6.12	9.6	12.4	14.8	19.3	20.2

* Heated to 1150 degrees Cent., (2100 degrees Fahr.) air cooled to 600 degrees Cent. (1112 degrees Fahr.).

Table IXa

Natural Ageing of Permanent Magnets

Treatment No. 1ally, Magnetized after hardening; stored in vertical position.

Steel & Bar No.	Ac_3 Degrees Cent.	Quench Temp. Degrees Cent.	Sclero-scope Hardness	(-Hc) oc	(-Hc) cc	After Hard-ening	When Stored	After 40 days	After 58 days	After 145 days	After 290 days	After 323 days	
98–1	Ac? 867	878	85	51.0	37.5	8721	8721	8584	8507	8294	7737	7680	*Brem*
							0	1.6	2.45	4.86	11.3	11.9	% Loss
97–1	785	795	70	44.5	31.0	7720	7356	7129	7039	6847	6367	6274	
							0	3.1	4.23	6.92	13.4	14.7	
99–1	840	850	79	122.8	103.8	9045	8766	8766	8715	8553	8065	7980	
							0	0.0	0.58	2.37	8.0	8.97	
98–4	763	773	78	50.0	36.7	8613	8613	8454	8335	8104	7601	7445	
							0	1.9	3.22	5.90	11.7	13.6	
97–5	785	875	75	44.5	31.7	7567	7567	7362	7220	7055	6566	6418	
							0	2.7	4.58	6.76	13.22	15.2	
97–6	785	950	74	43.2	31.0	7359	7359	7180	7084	6921	6418	6271	
							0	2.42	3.74	5.95	12.7	14.8	
99–4	840	900	82	126.1	107.1	8834	8834	8897	8787	8687	8152	8042	
							0	0.0	0.54	1.7	7.7	8.9	
99–5	840	950	84	136.5	122.7	8613	8613	8675	8582	8439	7934	7875	
							0	....	0.35	2.0	7.9	8.6	
Average Per Cent Loss								1.5	2.5	4.5	10.7	12.1	

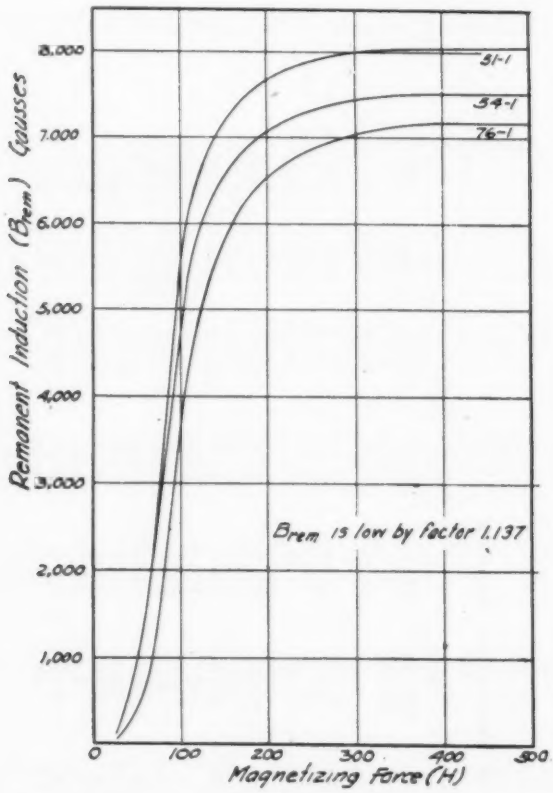


Fig. 9—Saturation Curves Showing the Variation of Remanent Induction (Brem) with Magnetizing Force (H) for Carbon Steels. Steels 51-1, 54-1 and 76-1 are Represented.

The remanent inductions for each bar in the following tables were figured from the last two equations by substituting the following numbers for the letters, and are accurate to about 1 per cent.

a=area of primary coil=81.071 square centimeters
N = 8 primary turns per centimeter
I = current in amperes
S = 785 turns on secondary
S′ = 100 turns on test coil

Determination of Open Circuit Coercive Force $(-H_c)_{oc}$

The bars were tested for open circuit coercive force by lowering them into a holder at the center of the mutual inductance primary, the center of the bar being in the center of the solenoid. The movable coil (No. 1, Fig. 3) was then lowered so that the coil came around the middle of the magnet. Increasing increments

of a reversed magnetic force were then applied and broken; the movable coil was then pulled out by a string, cutting the lines of force in the magnet and producing different ballistic deflections. When the magnetomotive force (H) applied was too strong the bar would be magnetized in the reverse direction and the ballistic galvanometer would deflect in the reverse direction. These increments of field strength were taken so that the magnetomotive force could be plotted against the ballistic deflection and the point obtained by extrapolation where the induction in the bar was zero. Fig. 4 shows how this was done. If the bars were remagnetized and the proper open circuit coercive field made and broken on the solenoid, the bars would be found to have a zero deflection and zero induction when the movable coil was jerked out.

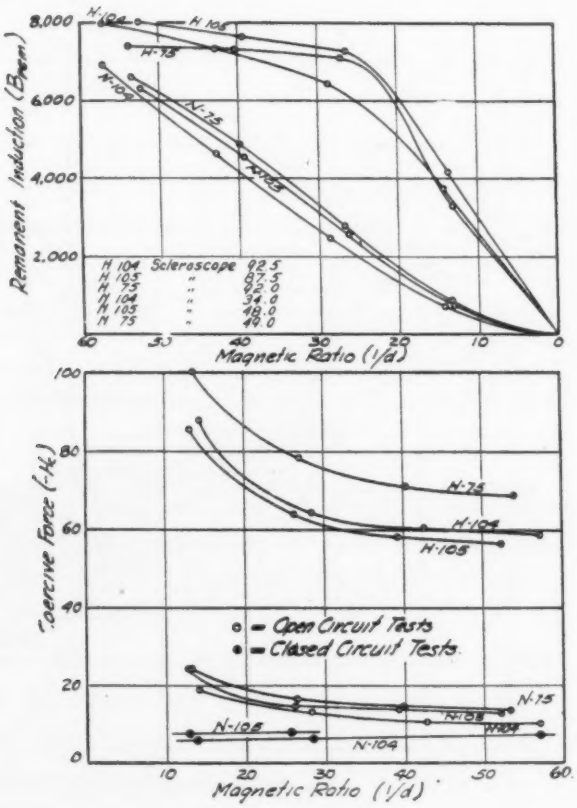


Fig. 10—The Upper Curves Show the Effect of Magnetic Ratio (l/d) on Remanent Induction (Brem) in Bar Magnets of Normalized and Hardened Steels. The Lower Curves Show the Effect of Magnetic Ratio (l/d) on Coercive Force (—Hc) in Open and Closed Circuits for Normalized and Hardened Bars.

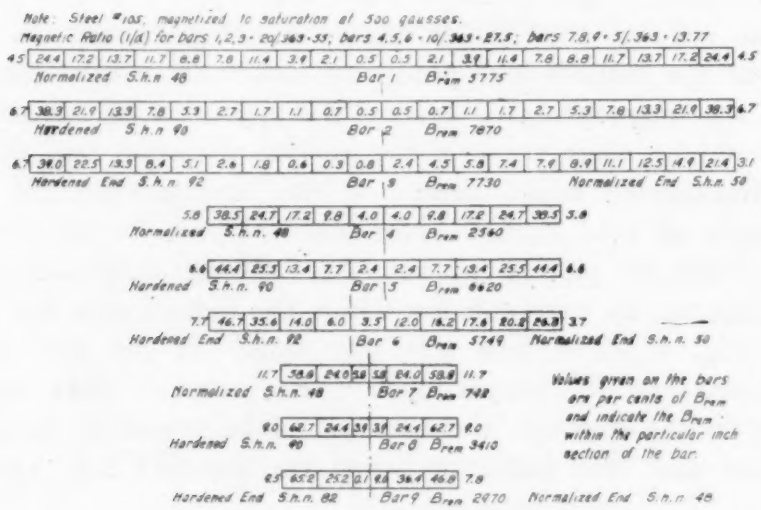

Note: Steel #105, magnetized to saturation at 500 gausses.
Magnetic Ratio (l/d) for bars 1, 2, 3 - 20/.363 = 55; bars 4, 5, 6 - 10/.363 = 27.5; bars 7, 8, 9 = 5/.363 = 13.77
Normalized S.h.n 48
Bar 1
Hardened S.h.n 90
Bar 2
Hardened End S.h.n. 92
Bar 3
Normalized End S.h.n. 50
Normalized S.h.n. 48
Bar 4
Hardened S.h.n. 90
Bar 5
Hardened End S.h.n. 92
Bar 6
Normalized End S.h.n. 50
Normalized S.h.n. 48
Bar 7
Hardened S.h.n. 90
Bar 8
Hardened End S.h.n. 82
Bar 9
Normalized End S.h.n. 48
Values given on the bars are per cents of Brem and indicate the Brem within the particular inch section of the bar.

Fig. 11—Distribution of Remanent Induction in Bar Magnets as Influenced by Magnetic Ratio (l/d) and by Heat Treatment.

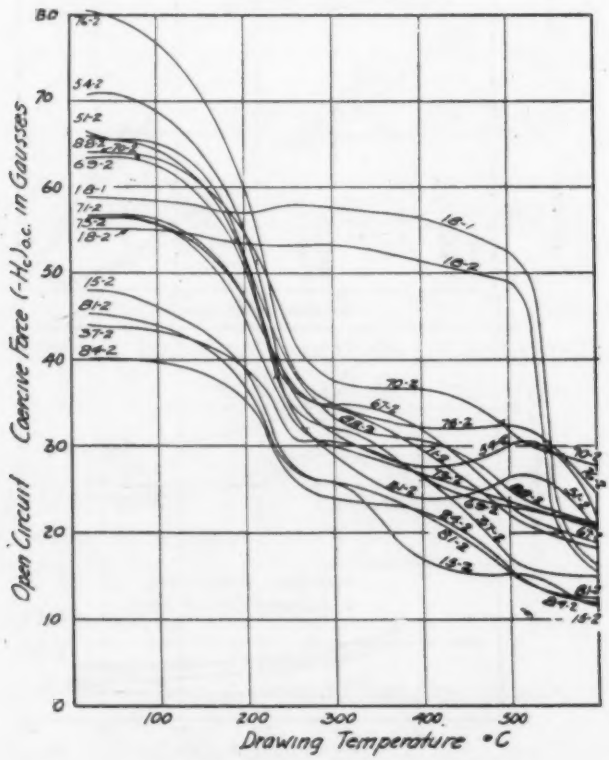


Fig. 12—The Variation of Coercive Force (—Hc)o.c. with Drawing Temperature. All Steels were Hardened in Tap. Water and Air Cooled from the Drawing Temperatures. All Steels were Magnetized at 500 Gausses after each Draw and (—*Hc*)*o.c.*, determined. Steels given Cumulative Draws for One Hour at 50, 100, 200, 260, 300, 400, 500, 600 and 700 Degrees Cent.

Determination of Closed Circuit Coercive Force $(-H_c)_{cc}$

In the usual magnetic testing the coercive force is determined similar to the $(-H_c)_{oc}$ test except that the reversed field is left on while the movable coil cuts the lines of force. In this case a calibration was obtained between the ballistic deflection of the movable coil (No. 1, Fig. 3) and H without a bar in the solenoid.

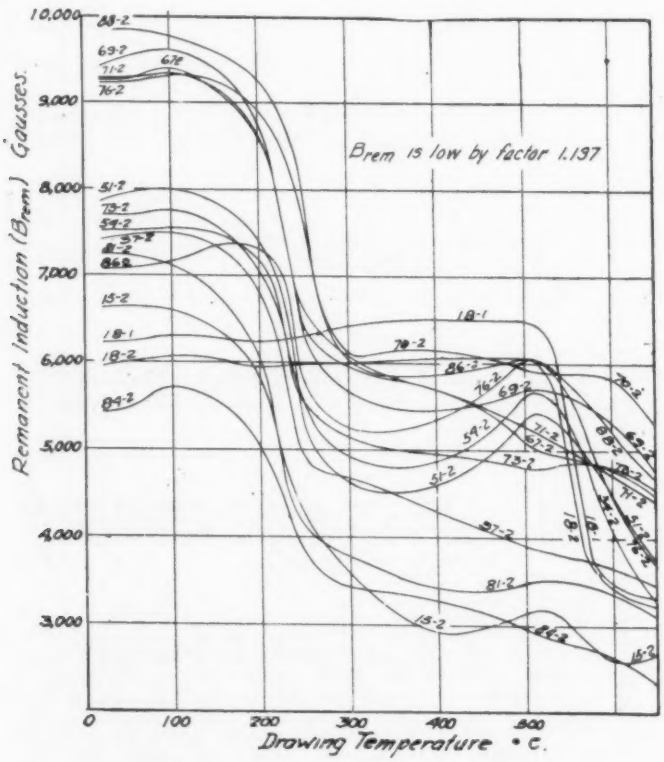


Fig. 13—The Variation of Remanent Induction (Brem) with drawing Temperature. All Steels were Hardened in Tap Water and Air Cooled from Drawing Temperatures. All Steels were Magnetized at 500 Gausses after each Draw. Draws were Cumulative at 50, 100, 200, 260, 300, 400, 500, 600 and 700 Degrees Cent. for One Hour.

This calibration curve gave a correction for the H value in the solenoid when the bar had zero induction. This correction was then applied to the curve, as shown in Fig 4, and the $(-H_c)_{cc}$ determined by extrapolation as before. This checks absolutely with a permeameter.

Demagnetizing

Whenever the magnets were to be demagnetized, it was done by slowly pulling them through the demagnetizing solenoid with

Table X

Natural Ageing of Permanent Magnets

Treatment No. 2, Aged in hardened condition for 9 months and 15 days; magnetized and stored in vertical position.

Steel & Bar No.	Ac_3 Degrees Cent.	Quench Temp. Degrees Cent.	Sclero-scope Hardness	When Stored	After 4 days	After 105 days	After 225 days	After 375 days		After Remagneti-zation
51–4	750	760	95.0	8908	8903	8794	8482	8234	*Brem*	8446
				0	0.04	1.3	4.8	7.6	% Loss	
54–4	735	745	91.0	7504	7410	7311	6964	6651		7123
				0	1.25	2.6	7.2	11.4		
76–4	800	810	94.5	7874	7817	7669	7453	7136		7401
				0	0.72	2.6	5.4	9.4		
69–4	760	770	90.0	11171	10477	10261	9994	9742		9931
				0	1.2	3.2	5.7	8.12		
73–4	750	760	67.0	7146	6987	6887	6714	6464		6639
				0	2.2	3.6	6.1	9.6		
70–4	765	775	96.0	10261	10261	10102	9866	9499		9687
				0	0	1.6	3.9	7.4		
15–4	680	690	79.0	7476	7373	7356	6902	6617		7044
				0	1.4	1.6	7.7	11.5		
81–4	705	715	65.0	5821	5782	5577	5463	5276		5497
				0	0.68	4.2	6.2	9.4		
84–4	721	731	66.0	5713	5662	5596	5406	5224		5816
				0	0.9	2.1	5.7	8.6		
37–4	715	725	83.0	8357	8294	8215	7913	7641		7329
				0	0.7	1.7	5.3	8.6		
18–3	825	835	65.0	6953	6947	6936	6686	6487		6604
				0	0.08	0.24	3.8	6.7		
Average Per Cent Loss.....					0.84	2.24	5.61	8.9		

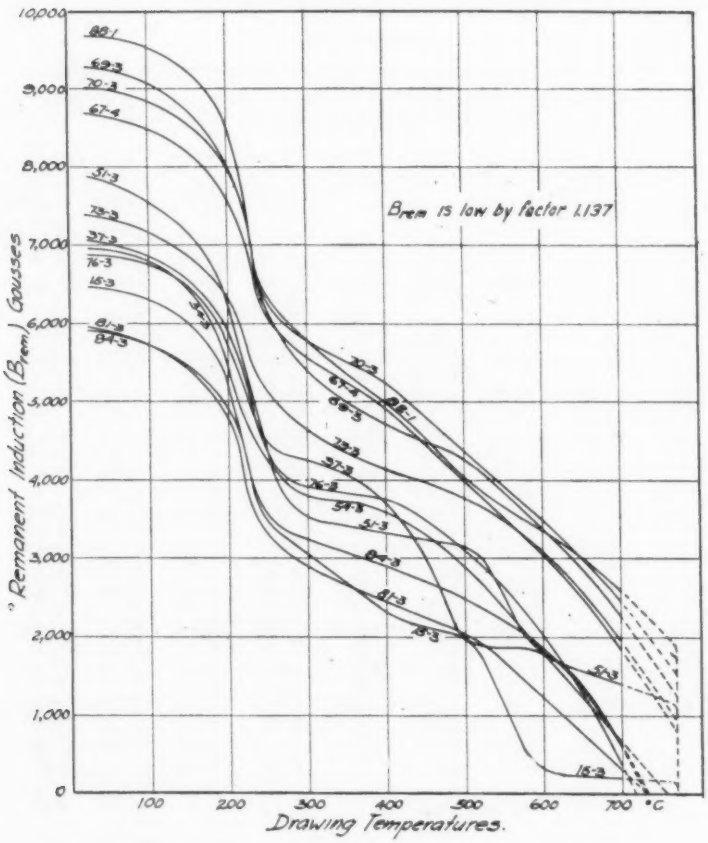


Fig. 14—The Variation of Remanent Induction (*Brem*) with Drawing Temperatures for Magnetized Bars. All Steels were Hardened in Tap Water and Air Cooled from Drawing Temperatures. The Bars were Magnetized after Hardening and Similar Pairs Coupled in Series by Wrought Iron Yokes which Remained on Throughout the Drawing Operation. The Steels were given Cumulative Draws at 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700 and 800 Degrees Cent.

an alternating current field slightly higher than the direct current field used for magnetizing. This was quite satisfactory in eliminating all induction in the magnets.

Results of Magnetic Tests

Effect of Intensity of Magnetizing Field on the Remanent Induction of Permanent Magnets

Figs. 5 to 9 inclusive, show the value of magnetomotive force necessary to saturate the magnets. The data for these graphs can be found in Table III.

Table XI

Artificial and Natural Ageing of Permanent Magnets

Treatment No. 3, Magnetized after hardening; demagnetized and drawn at 75 degrees Cent. for 4 hours. Remagnetized and aged in vertical position.

Steel & Bar No.	Ac_3 Deg. Cent.	Quench Temp. Deg. Cent.	Sclero-scope Hard-ness	After Hard-ening	After Draw	When Stored	After 15 days	After 102 days	After 226 days	After 369 days	After Remag-netiza-tion
51–25	750	760	88.0	8666	8681	8681	8613	8601	8232	7976	8207 B_{rem}
					+0.17	0	0.79	0.9	5.2	8.1	% Loss
54–25	735	745	93.0	7993	8036	8036	7959	7766	7643	7381	7601
					+0.54	0	0.96	3.4	4.9	8.2	
76–25	800	810	90.5	7493	7469	7469	7362	7300	7106	6831	8153
					−0.32	0	1.43	2.3	4.9	8.6	
69–25	760	770	84.0	10688	10711	10711	10559	10449	10074	9880	10117
					+0.22	0	1.4	2.4	5.9	7.8	
73–25	750	760	84.0	10813	10744	10744	10608	10347	10216	9925	10153
					−0.53	0	1.3	3.7	4.9	7.6	
88–25	761	771	98.0	11029	10972	10972	10858	10858	10449	10222	8153
					−0.52	0	1.0	1.0	4.8	6.8	
67–3	765	775	91.0	11131	11083	11083	10961	10870	10481	10193	10432
					−0.43	0	1.1	1.9	5.4	8.0	
70–25	765	775	92.5	10034	9943	9943	9863	9865	9460	9218	9437
					−0.9	0	0.8	0.8	4.91	5.9	
71–25	765	775	89.0	10375	10312	10312	10150	10119	976	9460	9767
					−0.6	0	1.6	1.9	5.8	8.3	
18–15	825	835	69.5	6896	6892	6892	6879	6799	6566	6457	6504
					−0.5	0	0.2	1.35	4.7	6.3	
15–25	680	690	83.5	8226	8513	8513	7843	7834	7567	7118	7561
					+3.5	0	7.9	8.0	11.2	16.4	
81–25	705	715	84.0	8496	8283	8283	8128	8042	7794	7516	7669
					−2.5	0	1.9	2.9	5.9	9.3	
84–25	721	731	76.0	7491	7419	7419	7305	7248	6992	6534	7010
					−1.0	0	1.5	2.3	5.7	11.9	
37–25	715	725	83.5	8516	8357	8357	8158	8061	7828	7566	7845
					−1.9	0	2.4	3.54	6.3	9.5	
				Average Per Cent Loss.....			1.7	2.6	5.7	8.8	
							41 days	59 days	149 days		
98–2	867	878	85.0	9051*	8704	8704	8699	8582	8437		8570
					−3.8	0	0.05	1.4	3.1		
97–2	785	795	73.0	7828*	7425	7425	7331	7235	7084		7254
					−5.2	0	1.3	2.6	4.6		
99–2	840	850	78.0	9085*	8817	8817	8817	8767	8598		8677
					−2.9	0	0.0	0.6	2.5		
				Average Per Cent Loss.....			0.4	1.5	3.4		

* Drawn 15 hours.

Effect of the Surface Finish of Permanent Magnets on Their Retentivity

The data in Table IV shows the per cent loss of five bar magnets having different surface finishes.

Influence of Notches and Cracks in Magnets

As some of the hardened bars showed slight cracks (usually running lengthwise of the bar) it was decided to determine the effect of the cracks and notches on the B_{rem}. Several 10-inch bars, which were broken into 5-inch lengths and put back together for testing, showed about a 20 per cent loss of B_{rem}. A notch was

Table XII

Artificial and Natural Ageing of Permanent Magnets

Treatment No. 4, Magnetized after hardening; demagnetized and drawn at 150 degrees Cent. for 7 hours. Remagnetized and aged in vertical position.

Steel & Bar No.	Ac_3 Deg. Cent.	Quench Temp. Deg. Cent.	Sclero-scope Hard-ness	After Hard-ening	After Draw	When Stored	After 9 days	After 127 days	After 241 days	After 363 days	After Remag-netiza-tion	
51-36	750	760	76.0	8351	7942	7942	7879	7766	7663	7356	7493	B_{rem}
					—4.9	0	0.8	2.1	3.5	7.4		% Loss
54-36	735	745	92.0*	8130	7936	7936	7868	7834	7550	7376	6718	
					—2.4	0	0.9	1.3	4.9	7.1		
76-36	800	810	92.0*	7538	7730	7730	7629	7572	7345	7194	7295	
					+2.6	0	1.32	2.0	5.0	6.9		
69-36	760	770	76.0*	10580	9949	9949	9858	9780	9437	9269	9423	
					—5.96	0	0.9	1.7	5.2	6.8		
73-36	750	760	82.5	10844	10426	10426	10252	10119	9825	9608	9837	
					—3.8	0	1.7	2.9	5.8	7.8		
88-16	761	771	86.5*	10688	10176	10176	10096	10000	9653	9426	9625	
					—4.8	0	0.8	1.7	5.1	7.4		
67-46	765	775	88.4*	10244	9539	9539	9401	9380	9016	8847	9062	
					—9.9	0	1.4	1.7	5.4	7.3		
70-36	765	775	86.0	9954	9665	9665	9585	9585	9221	8986	9151	
					—2.9	0	0.8	0.8	4.6	7.0		
18-26	825	835	71.6	6750	6741	6741	6714	6663	6487	6336	6401	
					—0.13	0	0.24	1.2	3.8	6.0		
15-36	680	690	75.0	7982	6992	6992	6845	6820	6600	6447	6563	
					—12.4	0	2.1	2.5	4.0	7.8		
81-36	705	715	75.0	7311	6367	6367	6231	6197	5997	5815	6026	
					—12.9	0	2.1	2.7	5.8	8.7		
84-36	721	731	78.0	8209	7260	7260	7105	7061	6822	6657	5855	
					—11.6	0	2.1	2.7	6.0	8.3		
37-36	715	725	71.0	8471	7652	7652	7592	7504	7309	7073	7253	
					—9.7	0	0.8	1.9	4.5	7.6		
					Average Per Cent Loss.....		1.2	1.9	4.9	7.4		
							41 days	59 days	149 days			
98-3	867	878	87.0	9016	8014	8014	8014	7923	7809		7937	
					—11.1	0	0	1.1	2.6			
97-3	785	795	74.0	7612	6657	6657	6634	6557	6441		6527	
					—12.6	0	0.34	1.5	3.3			
99-3	840	850	79.0	9051	8857	8857	8937	8813	8695		8723	
					—2.4	0	1.2	0.24	1.6			
					Average Per Cent Loss.....		0.5	0.9	2.5			

* Drawn 11½ hours.

cut 1/16 inch wide and half way through a 10-inch bar but made it lose only about 7 per cent of its B_{rem}.

Influence of Direct Current and Alternating Current Magnetic Fields During Hardening on the Remanent Induction of Magnets

The effect of direct current and alternating current magnetic fields during quenching on the B_{rem} of magnets is shown in Table V. In these experiments a combination of brass quenching tank and solenoid (3-inch diameter tube, 48 inches long, wound with 2936 turns of No. 15 copper wire) was used, through which tap water was kept running constantly. All of the bars in each heat

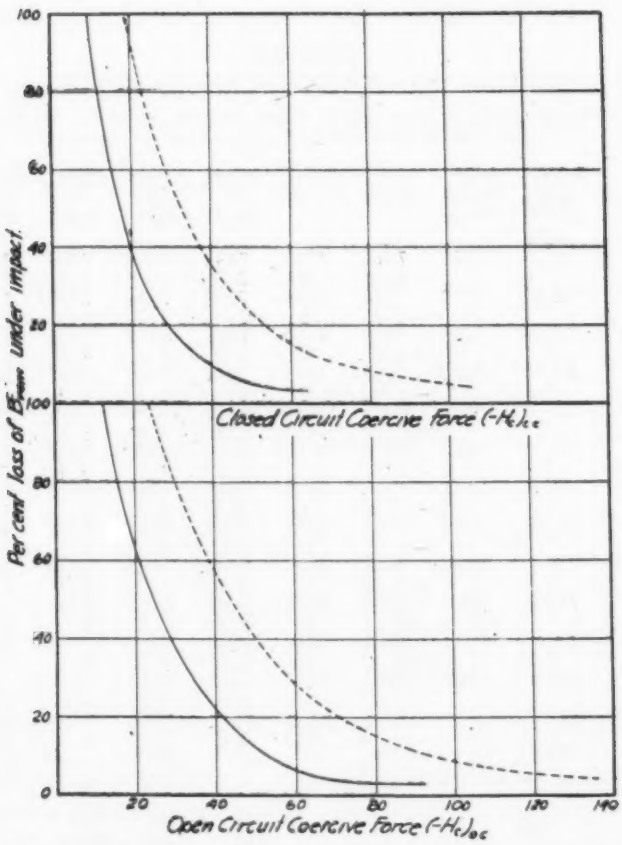


Fig. 15—Relation of Per Cent Loss of Remanent Induction Under Impact to Coercive Force for Various Steels. Bars were 10 Inches by 0.375 Inches ± 0.01. Impact Blows of 945-one foot pound over a Period of 45 minutes were Applied to each Bar. The Bars were Magnetized at 500 Gausses.

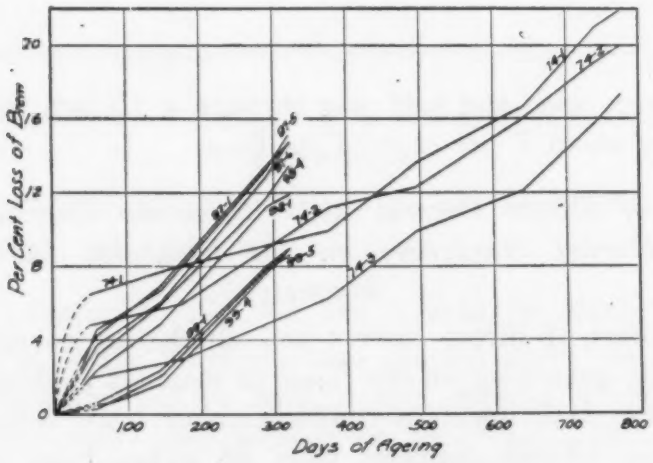


Fig. 16—Effect of Quenching Temperature on the Per Cent Loss of Brem in the Natural Ageing of Bar Magnets. Steel and Bar Numbers are Indicated on the Curves.

Table XIII

Artificial and Natural Ageing of Permanent Magnets

Treatment No. 5, Magnetized after hardening; remagnetized and drawn at 100 degrees Cent. in air until approximately 5 Per Cent of *Brem* was lost; aged in vertical position.

Steel & Bar No.	Ac_3 Deg. Cent.	Quench Temp. Deg. Cent.	Held at 100 Deg. Cent. for	After Hardening	After Draw	After Sacrifice	When Stored	After 3 days	After 19 days	After 140 days	After 175 days
51-360	750	760	40 min.	8182	7754	.....	7754	.....	7305	7229	7046 *Brem*
					—5.2	.....	0	.....	5.8	6.8	9.1 % Loss
54-250	735	770	40 min.	8286	7472	.....	7472	7471	7128	6989	6803
					— 9.8	.....	0	0	4.6	6.5	8.9
69-250	760	795	40 min.	10156	9423	.....	9423	9381	8973	8832	8622
					— 7.2	.....	0	0.45	4.8	6.3	8.5
88-160	761	771	40 min.	10242	9687	.....	9687	9664	9241	9049	8838
					— 5.4	.....	0	0.23	4.6	6.6	8.8
67-30	765	800	40 min.	10238	9574	.....	9574	9542	9155	8964	8800
					— 6.5	.....	0	0.33	4.4	6.4	8.1
15-250	680	715	25 min.	7630	6898	.....	6898	6897	6572	6401	6298
					— 9.6	.....	0	0.28	4.72	7.2	8.7
81-250	705	715	25 min.	7669	6776	.....	6776	6733	6396	6246	6140
					—11.6	.....	0	0.64	5.6	7.8	9.4
37-360	715	725	25 min.	8277	7663	.....	7663	.....	7220	7148	6955
					— 7.5	.....	0	.....	5.8	6.7	9.2
98-20	867	878	25 min.	8632	8061	.....	8061	7985	7637	7426	7341
					— 6.6	.....	0	0.95	5.3	7.9	8.9
99-20	840	850	45 hrs.	8947	8613	.....	8613	.....	8221	8220	8035
					— 3.7	.....	0	.....	4.7	4.7	6.7
					Average Per Cent Loss.....			0.4	5.0	6.7	8.1

Treatment No. 6, Magnetized after hardening; remagnetized and drawn at 100 degrees Cent., in air until approximately 5 Per Cent of *Brem* was lost; bar partly demagnetized in reversed field until approximately 5 Per Cent more of *Brem* was lost; aged in vertical position.

54-360	735	770	47 min.	7919	7587	7257	7257	7211	6876	6697	6550
					—4.2	.....	0	0.64	5.3	7.7	9.7
69-360	760	770	20 min.	11017	9653	9162	9162	9120	8721	8618	8462
					—3.6	.....	0	0.46	4.8	5.9	7.6
88-250	761	796	20 min.	10335	9815	9380	9380	9289	8843	8786	8618
					—5.05	.....	0	0.97	5.7	6.3	8.1
67-460	765	775	15 min.	9355	8935	8457	8457	8414	7948	7941	7705
					—4.5	.....	0	0.51	6.0	6.1	8.9
15-360	680	715	20 min.	7348	6741	6422	6422	6388	6064	5929	5835
					—8.3	.....	0	0.53	5.6	7.7	9.14
81-360	705	715	15 min.	6924	6435	6140	6140	6127	5774	5642	5545
					—7.1	.....	0	0.20	6.0	8.1	9.7
98-30	867	878	20 min.	8636	8040	7666	7666	7616	7263	7103	6997
					—6.9	.....	0	0.65	5.3	7.3	8.7
99-30	840	850	45 hrs.	9088	8715	8300	8300	.....	.....	8243	8130
					—4.1	.....	0	.....	.....	0.69	2.1
					Average Per Cent Loss.....			0.6	5.5	6.2	8.2

of this test were taken alternately from the hardening furnace and quenched in the water bath surrounded by the different magnetic fields. After this treatment the bars were all magnetized and tested for B_{rem}. The bars were given the high temperature quench from 900 degrees Cent. (1650 degrees Fahr.) so that they would have more time in going through the solid solution range giving the different magnetic fields a greater opportunity to act.

Table XIV

Artificial and Natural Ageing of Permanent Magnets

Treatment No. 7, Magnetized after hardening; demagnetized and drawn at 100 degrees Cent., for 12 hours and remagnetized. Magnetized bar drawn at 100 degrees Cent. in air until approximately 5 per cent of *Brem* was lost; aged in vertical position.

Steel & Bar No.	Ac_3 Degrees Cent.	Quench Temp. Degrees Cent.	Held at 100 Degrees Cent. for	After Hard-ening	After Demag. Drawn	After Mag. Drawn	After Sacri-fice	When Stored	After 3 days	After 19 days	After 140 days	After 175 days
76–250	800	810	50 Min.	7413	7480	7192		7192	7169	6794	6748	6630 *Brem*
					+0.9	—.39		0	0.3	5.5	6.2	7.8% Loss
73–250	750	785	25 Min.	8313	8402	7964		7964	7958	7516	7498	7350
					+1.1	—5.2		0	0.1	5.6	5.8	7.7
70–250	765	800	75 Min.	9409	9383	9016		9016	9016	8631	8555	8390
					—0.3	—3.9		0	0	4.3	5.1	6.9
18–150	825	860	25 Min.	5823	6306	5600		5600	5594	5294	5272	5152
					+8.3	—11.2		0	0.1	5.4	5.9	8.0
84–250	721	756	25 Min.	5640	5790	5474		5475	5418	5102	5105	4990
					+2.7	—5.5		0	0.1	6.8	6.7	8.9
97–20	785	820	25 Min.	7650	7388	9019		7019	6998	6621	6586	6450
					—3.4	—5.0		0	0.3	5.7	6.2	8.1
					Average Per Cent Loss.....				0.15	5.5	6.0	7.9
Treatment No. 8, Same as No. 7 except that 5 Per Cent more of *Brem* was sacrificed in a reversed field before ageing.												
76–360	800	810	40 Min.	7097	7106	6811	6496	6496	6427	6128	6107	5990
					+0.1	—4.2		0	1.0	5.6	6.0	7.8
73–360	750	785	20 Min.	8931	9130	8726	8226	8226	8152	7769	7743	7595
					+2.2	—4.4		0	0.9	5.6	5.8	7.7
70–360	765	775	40 Min.	9306	9130	8742	8300	8300	8269	7882	7891	7712
					—1.9	—4.2		0	0.4	5.0	4.9	7.1
18–250	825	860	20 Min.	6085	6094	5865	5350	5350	5295	5088	5033	4920
					+0.1	—3.8		0	1.0	4.9	5.9	8.0
84–360	721	731	20 Min.	7845	7811	7305	6936	6936	6845	6538	6506	6375
					—0.4	—6.5		0	1.3	5.7	6.2	8.1
97–30	785	820	20 Min.	7595	7388	6922	6551	6551	6486	6202	6168	6039
					—2.7	—6.3		0	1.0	5.3	5.8	7.8
					Average Per Cent Loss.....				0.9	5.4	5.8	7.7

Table XV

Artificial and Natural Ageing of Permanent Magnets

Treatments: Magnetized after hardening.

* Bar demagnetized and drawn at 100 degrees Cent., for 10 hours and remagnetized.

** Bar demagnetized and drawn at 100 degrees Cent., for 20 hours and remagnetized.

*** Magnetized bar repeatedly quenched from water bath at 100 degrees Cent., in ice water at 0 degrees Cent., after holding 5 minutes at each until approximately 5% of *Brem* was lost.

Magnetized bar given 10 quenches from water at 100 degrees Cent., to ice water at 0 degrees Cent., holding 5 minutes at each temperature.

Aged in vertical position.

Treatment	Steel & Bar No.	Ac_3 Degrees Cent.	Quench Temp. Degrees Cent.	Scleroscope Hardness	After Hardening	After *	After **	After ***	After 10 Quenches	When Stored	After 15 days	After 84 days	After 125 days	After 136 days	After 171 days
No. 9	51–250	750	785		8128			7720	(Q 7X)	7720	7343			7222	7087 *Brem*
								—5.0		0	4.9			6.5	8.2% Loss
No. 9	37–250	715	725		8118			7734	(Q 5X)	7734	7282			7222	6951
								—4.7		0	5.8			6.6	10.1
No. 10	105–1	740	750	91.0	7710	7610			7222	7222		7176	7090		
						—1.3			—6.3	0		0.6	1.8		
No. 10	105–2	740	750	91.0	7535	7336			6953	6953		6907	6803		
						—1.1			—5.1	0		0.7	2.2		
No. 11	105–3	740	750	90.0	7427		7392		6774	6774		6725	6619		
							—0.5		—8.4	0		0.7	2.3		
No. 11	105–4	740	750	90.0	7595		7546		7072	7072		7023	6920		
							—0.6		—6.3	0		0.7	2.2		
No. 12	105–5	740	750	90.0	7925				7072	7072		7023	6871		
									—10.8	0		0.7	2.8		
No. 13	105–11	740	820	90.0	6936	6936				6493		6470	6348		
						0				0		0.4	2.2		
No. 13	105–12	740	820	89.5	6686	6638				6306		6306	6202		
						—0.7				0		0.0	1.7		
No. 14	105–13	740	820	89.0	6941		6969			6603		6506	6425		
							+0.4			0		1.5	2.7		
No. 14	105–14	740	820	89.5	6742		6765			6115		6068	5980		
							+0.3			0		0.8	2.2		

Effect of Magnetic Ratio (1/d) on the Remanent Induction and Coercive Force of Normalized and Hardened Steels

The effect of magnetic ratio on the $B_{rem.}$ and $(-H_c)$ of normalized and hardened steels is shown in Fig. 10. This graph is drawn from the data on three carbon steels only but its form would probably be representative of most of the different compositions.

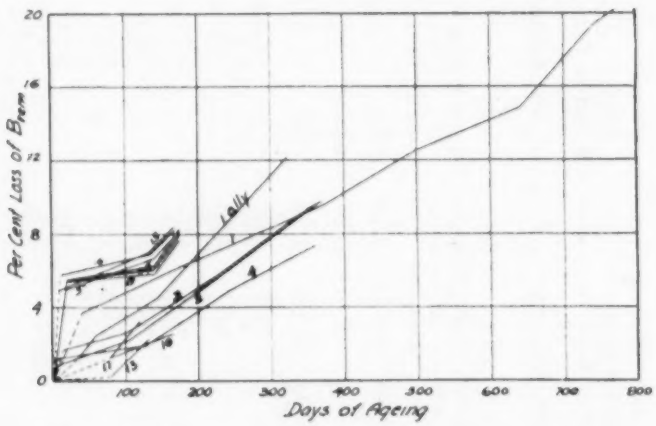


Fig. 17—Effect of Various Treatments on the Average Per Cent Loss of *Brem* in the Ageing of Miscellaneous Bar Magnet Steels. Steel and Bar Numbers are Indicated on the Curves.

Distribution of Remanent Induction in Bar Magnets as Influenced by Magnetic Ratio and by Heat Treatment

Fig. 11 shows the percentage distribution of the total flux within each 1-inch section of the different length bars. These B_{rem} determinations were made by slipping off a small test coil (surrounding the bar) from these different sections of the magnet.

The Variation of Open Circuit Coercive Force With Drawing Temperature

Data giving the effect of drawing temperature on the open circuit coercive force is given in Table VI. This data is graphically represented in Fig. 12. The procedure in this test was as follows: The bars were magnetized to saturation and tested for $(-H_c)_{oc}$. They were then demagnetized and given cumulative draws for one hour followed by an air cooling. After each draw they were remagnetized and tested. The cumulative draws were at 50, 100, 200, 260, 300, 400, 500, 600, and 700 degrees Cent.

Table XVI

Artificial and Natural Ageing of Permanent Magnets

Treatment No. 15, Magnetized after hardening; magnetized bar quenched from 20 degrees Cent. in carbon dioxide snow at —57 degrees Cent., after being held in the snow until approximately 5 Per Cent of *Brem* was lost. Aged in vertical position.

Steel & Bar No.	Ac_3 Deg. Cent.	Quench Temp. Deg. Cent.	Sclero-scope Hard-ness	After Hard-ening	After Draw	After Sacri-fice	When Stored	After 11 days	After 133 days	After 167 days	Held in snow for Min.
51-40	750	785	...	8348	...	7936	7936	7572	7462	7330	90 *Brem*
						—4.9	0	4.6	6.0	7.6	% Loss
54-40	735	745	...	7771	...	7334	7334	6885	6759	6660	20
						—5.6	0	6.1	7.8	9.1	
69-40	760	795	...	7891	...	9682	9682	9304	9096	8949	125
						—6.1	0	3.9	6.1	7.6	
71-250	765	775	...	9769	...	9334	9334	8933	8789	8665	115
						—4.5	0	4.3	5.8	7.2	
18-30	825	860	...	5535	...	5277	5277	5044	4974	4935	40
						—4.7	0	4.4	5.7	6.5	
15-40	680	715	...	7397	...	7027	7027	6646	6392	6315	40
						—5.0	0	5.4	9.0	10.1	
81-40	705	715	...	5622	...	5329	5329	5022	4861	4770	35
						—5.2	0	5.8	8.7	10.4	
					Average Per Cent Loss.....			4.9	7.0	8.4	

Treatment No. 16, Same as No. 15 except that the bars were demagnetized and drawn at 100 degrees Cent. for 12 hours; then remagnetized before the carbon dioxide quenches.

76-40	800	810	...	7659	7505	7401	7401	6884	6782	6735	65
					—2.0	—1.4	0	7.0	8.4	9.0	
73-40	750	760	...	5065	5086	4810	4810	4516	4449	4416	40
					+0.4	—5.5	0	6.1	7.5	8.2	
70-40	765	800	...	9471	9280	9019	9019	8656	8562	8436	247
					—2.0	—2.8	0	4.0	5.1	6.5	
84-40	721	731	...	5526	5514	5224	5224	4920	4849	6735	23
					—2.0	—5.3	0	5.8	7.1	9.3	
37-40	715	725	...	8453	8232	7959	7959	7543	7436	7328	60
					—2.6	—3.3	0	6.2	6.6	7.9	
					Average Per Cent Loss.....			5.8	6.9	8.2	

Treatment No. 17, Magnetized after hardening; demagnetized and drawn at 100 degrees Cent. and remagnetized; quenched 5 times in CO_2 snow from water at 100 degrees Cent., and held 5 minutes in each.

								81 days	115 days	
105-6	740	750	91.0	7595	7447	7123	7123	7072	6970	Drawn 10 hrs.
					—1.9	—4.3	0	0.7	2.2	
105-7	740	750	91.0	7163	7163	6785	6785	6640	6585	Drawn 20 hrs.
					0.0	—5.3	0	2.1	3.0	
105-9	740	750	94.0	7688	7542	7163	7163	7118	7008	Drawn 20 hrs.
					—0.4	—5.0	0	0.6	2.2	
105-10	740	750	87.0	7481	.....	6806	6806	6617	6510	Not drawn.
						—9.0	0	1.8	4.3	
					Average Per Cent Loss.....			1.3	2.9	

The Variation of Remanent Induction with Drawing Temperature

Data giving the effect of drawing temperature on B_{rem} is also given in Table VI and graphically represented in Fig. 13. The procedure in this test was the same as above.

The Effect of Drawing Temperature on the Remanent Induction While in the Magnetic State

Data giving the effect of drawing temperature on the B_{rem} while in the magnetic state are given in Table VII. In this series the bars were magnetized to saturation and tested for B_{rem}. Similar bars were then yoked with wrought iron yokes of 3/4-inch square stock with 3/8-inch holes drilled 1/2 inch deep and 1 3/4 inches apart. It was found that if these pairs of bars were magnetized and connected in series with these magnetized yokes, there was practically no loss of B_{rem} after standing several days. In this manner these bars were given cumulative draws for one hour at 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, and 800 degrees Cent. followed by air cooling. The yokes were off only during the test for B_{rem}.

Relation of the Per Cent Loss of Remanent Induction Under Impact to the Coercive Force for Various Steels

Various magnet steels were taken at random and given different quenches or draws to give them different coercive forces. These bars were magnetized, tested, and subjected to 21 foot-pound blows per minute over a period of 45 minutes, after which they were again tested in order to obtain their per cent loss. The 45-minute time limit was adopted because the per cent loss after 45 minutes was usually about 75 per cent of the loss obtained with 5 hours hammering. The first falls are the most effective.[6] The data for this test is given in Table XIII. Fig. 15 shows this data in graphical form. The dotted curve is drawn through the cobalt-chrome steel points.

Artificial and Natural Ageing of Permanent Magnets

Different artificial and natural ageing treatments were given the magnets which can be found by referring to Tables IX to XVI inclusive. In all natural ageing or storing treatments the bars were suspended in a vertical position from strings. They were kept 18 inches apart and all had their actual north poles up (not their north seeking poles). These bars were lightly greased with a rust proof oil to keep them from tarnishing. Fig. 16 shows the effect of different quenching temperatures on the per

6. Mme. Curie, loc. cit.

cent loss of B_{rem} in ageing. Fig 17 shows the effect of various treatments on the average per cent loss of B_{rem} in the ageing of miscellaneous bar magnet steels.

Conclusions

1. From the saturation curves (Figs. 5 to 9 inclusive) it is shown that all of the steels except No. 99 are saturated at 400 gausses or less. Cobalt-chrome steel No. 99 requires 500 gausses for saturation.

2. In the natural ageing of weak magnets, the rougher the surface finish the less is the per cent loss of B_{rem} (Table IV).

3. Small hardening cracks do not appreciably change the B_{rem} of a magnet. Of course they are to be avoided if bars are to be polished or plated as the cracks may retain water or plating solution which might later cause rust stains.

4. In subjecting magnets to the influence of a 60-cycle alternating magnetic field during the hardening operation and later magnetizing in the usual direct current field, it seems that the bars take a higher B_{rem} (Table V). On the other hand, bars quenched in a direct current field and later magnetized in the usual way showed a slightly lower B_{rem} than those quenched without the influence of a field.

5. The B_{rem} of hardened and normalized carbon steels is practically the same at a magnetic ratio of 60. The open and closed circuit coercive forces, however, show almost a constant difference for the different magnetic ratios of the hardened and normalized bars. (Fig 10).

6. In magnets of low magnetic ratio a greater percentage of the B_{rem} is near the end of the bar than is the case with high magnetic ratios.

7. The open circuit coercive force of hardened magnet steels decrease as the drawing temperature increases. The open circuit coercive force of a magnet seems to be just as good an indication of the condition of the magnet as the closed circuit value and is more easily determined.

8. The B_{rem} of some hardened magnet steels increases with a drawing temperature of around 100 degrees Cent. This increase is probably due to a small amount of austenite (non-magnetic) which draws to martensite (the most permanently magnetic micro-

constituent). (Fig. 13). The 15 per cent chromium steel is quite resistant to tempering action. As the bars are further drawn and troostite begins to form, there is a rapid falling off of $B_{rem.}$ At a drawing temperature around 500 degrees Cent. (932 degrees Fahr.) there is an increase in B_{rem} for all of the carbon steels, tungsten steels and nickel steels tested. The coercive force determinations also show an increase at this temperature for carbon and nickel steels. (Fig. 14). This phenomenon may be connected with the temper brittle range of steel.

9. As a general proposition the higher the coercive force of a magnet the more resistant it is to loss of B_{rem} under impact or shock. However, cobalt-chrome steel No. 99 has an exceptionally large coercive force but under impact has as great a loss of B_{rem} as any of the more common types of magnet steels. (Fig. 15).

10. In straight carbon steels the coercive force increases with carbon content while the B_{rem} decreases for all steels investigated. (Carbon 0.70 to 1.20)

11. As far as the writer has been able to determine, there seems to be no appreciable difference in the per cent loss of B_{rem} with natural ageing during winter or summer months in Minnesota climate.

12. The most satisfactory of the treatments given to the magnets for permanency was Treatment No. 10 (Table XV, Fig. 17), which was as follows:

1, Harden in tap water
2, Magnetize after hardening (unnecessary)
3, Demagnetize and draw at 100 degrees Cent. for 10 hours (Bars 10 x 3/8 inches)
4, Magnetize and quench 10 times in ice water (0-2 degrees Cent.) from boiling water (98-100 degrees Cent.) after holding 5 minutes at each temperature.

This is approximately the same treatment recommended by Gumlich[7] and probably similar to the ageing treatment given to magnets by the manufacturers.

13. The composition of magnet steel recommended (for open or closed circuit magnets) from this investigation is as follows:

	C	Mn	Si	P	S	Cr	W	Mo	Co
1, Steel No. 99	.86	.13	.16	.015	.041	9.31	...	1.24	13.66
2, Steel No. 70	.97	.74	.33	.031	.005	2.87	...	...	....
3, Steel No. 88	.76	.61	.56	.022	.011	0.41	5.08	...	....

7. Gumlich, Industrie chimique 9, 310 (1922). C. A. 16, 3853.

14. In hardening these steels the highest scleroscope hardness should be obtained. Operation 3 in the recommended treatment undoubtedly relieves some of the mechanical strain which is detrimental to permanency. After all of these operations on the magnet, it is still in a condition of unstable equilibrium as far as microstructure is concerned, so it is impossible to have an absolutely constant magnet.

ACKNOWLEDGMENT

The author takes the greatest of pleasure in acknowledging the valuable assistance and suggestions of Dr. O. E. Harder, professor of metallography at the University of Minnesota, at whose suggestion and under whose supervision this work was carried out.

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Acknowledgment is gladly made for certain financial assistance from the research fund of the graduate school of the University of Minnesota.

Much of the credit for aid in the preparation of this paper is due to Miss Carrie Green, assistant in the department of metallography.

Discussion of Mr. Dowdell's Paper

CHAIRMAN MERICA: Gentlemen, Mr. Dowdell's paper is before you for discussion.

A. V. deFOREST: Would the steels which would normally be expected to quench to an austenitic condition show a nonmagnetic character before the draw? I seem to recollect that the figure that would have shown that, gave a constant magnetic property right across to a fairly high drawing temperature. Is that a correct impression?

R. L. DOWDELL: Yes, that is right. High chromium steel had about 50 per cent of the number of lines of force that some of the best steels had, and seemed to hold that value with cumulative draws up to 500 degrees Cent. An all austenitic structure is nonmagnetic. The Hadfield high manganese steel seems to be a steel of this type.

A. V. deFOREST: Then the chrome steel would be a steel which would retain that coercive force it had up to a high drawing temperature.

R. L. DOWDELL: It is certainly an ideal steel if you are going to heat the magnet.

A. V. deFOREST: Is there any reason for the austenite in these chromium steels to act differently from the manganese steel austenite?

R. L. DOWDELL: I do not see that there is. There is probably in this case a small amount of martensite present. The carbon content of that steel was 0.11 per cent. In the stainless steels, of course, the carbon will run about 0.35 to 0.40 per cent and in this case we might have a somewhat different condition.

PROF. H. M. BOYLSTON: I would like to ask Mr. Dowdell if he examined these chromium steels under the microscope to determine whether the structure was actually austenitic or martensitic.

R. L. DOWDELL: These steels are difficult to examine, that is, to really check for martensite, because under the microscope there is a large amount of C—T constituent present, which more or less interferes with the martensitic needles, and from all indications, appears to be austenite. I have never found a real martensitic structure in any of these steels, that is, where the needles were resolved so one could actually say that it consisted entirely of martensite.

Dr. S. L. Hoyt spoke about that yesterday in discussing one of the papers that was presented. The way he explained it was that austenite seems to go more or less into troostite on drawing, without passing through the martensitic state, at least, as observed under the microscope. In other words, we might have a structureless martensite.

ELECTRICAL ENERGY ECONOMICAL FOR HEAT TREATING

By E. F. Collins

Abstract

This paper reviews in some detail the relative cost data in the operation of electric and fuel-fired furnaces pointing out that electrical heating is economical and comparable to fuel heating. In the operation of fuel-fired furnaces much depends upon the operator as to the efficiency of its operation. The paper summarizes some of the more important features of electric heating which distinguish it from fuel-fired equipment, discussing heat generation, heat conservation resulting in high thermal efficiency and methods of electric heat transmission and delivery to charge.

Introduction

HEAT energy application in furnaces in this country has in the past been largely the composite result of promotion and advertisement rather than of engineering. We have had fuel oil advocates, gas burning experts, powdered coal enthusiasts, fuel oil specialists, etc., but we have, until recently, lacked the competent furnace engineer familiar with all types of furnaces, who could sit as court of appeal and give unbiased decisions regarding the true economic value of various heat sources for a specific work.

To operate a certain process with gas, which might much more advantageously be carried out with other forms of energy, is not economy, yet many such cases exist today. There are many gas devices operating today which should have long since been scrapped in favor of the electrical.

Many manufacturers, engineers and executives unfamiliar with the possible economics of industrial electric heating dismiss it from their serious consideration, on the theory that its use is expensive and impractical. They reason that fuel furnaces liberate the heat of the fuel directly in the furnace where it is to be used, whereas the electric furnace must have its heat units supplied in form of electric energy. This means that electric energy must be generated from the B.t.u. of the fuel, involving thermal

A paper presented before the Boston chapter of the Society. The author, E. F. Collins, is consulting engineer on industrial heating, General Electric Co., Schenectady, N. Y.

losses in transferring (1) the heat energy of the fuel to steam, (2) the steam to mechanical energy, (3) the mechanical energy to electrical energy. If this reasoning be expressed in figures it runs as follows:

Good coal has a calorific value of 12,500 B.t.u. per pound and may be bought for $5 per ton, or ¼ cent per pound. Since 3415 B.t.u. equals 1 kilowatt hour then it follows that electric energy must be had for

$$\frac{3415}{12{,}500} \times \frac{1}{4} = \frac{1}{16}$$ cents per kilowatt hour. Hence electric heat should be about 16 times the cost of coal-firing, when used in industrial furnaces, assuming an average price of 1 cent per kilowatt hour for central station heating power. In the manner that this reasoning has been carried out these figures off-hand appear correct.

Contrasted to the above reasoning let us first turn our attention to the simple and homely smithy forge, with which we are all more or less familiar. Investigations concerning the thermic efficiency of the forge, which has remained practically unimproved in the course of centuries, have shown that the utilization of fuel in it is extremely inefficient. Its forge thermic efficiency does not exceed 9 per cent, that is, not more than 9 per cent of the fuel is converted into useful heat in the metal which is being worked. The balance, 91 per cent, escapes in the form of smoke and soot through the chimney, warms the work-shop, oft-times to an extent far in excess of what is desirable from a hygienic point of view, and heats the brick work of the forge, and so on.

In the metal which is being heated to redness or to working temperature, there is, therefore, only 9 per cent of the original energy utilized. Part of the heat is diverted from the metal due to the good conductivity of the metal, and usually the portion which it is desired to heat will not be heated uniformly. Also another portion is likely to be over-heated because the heating zone of the forge cannot be accurately limited. Exhaustive tests have shown that only about 3 per cent of the original energy stored in the coal is available for use in heating the desired portion of the metal. That is, the entire loss in energy on the old smithy forge will show an average loss of about 97 per cent, which practically

means that almost the entire bulk of the coal burned is wasted.

On the other hand, let us consider the heating of steels to temperatures around 1600 degrees Fahr. for annealing or hardening; also to the lower temperatures required for drawing, when this heating is accomplished through the use of electricity. The modern power station today gives a kilowatt hour of electric energy for the consumption of about 1½ pounds of coal; or an efficiency of about 20 per cent. In other words, 20 per cent, roughly, of the total energy of the fuel is converted into electricity. The electric furnace at 1600 degrees Fahr. when properly designed and applied, readily gives efficiencies of 80 per cent, which means that we would have effective in heating the metal, 16 per cent of the B.t.u. in the coal burned by the central station.

In the case of forging equipments, which have employed electric heat both in the form of furnaces and in the form of equipment whereby the forging blank is heated by passing current through it, over-all efficiencies of 50 to 60 per cent have been realized. At these higher temperatures, say, of 2300 degrees Fahr., we have, by the electric method, been able to utilize 10 to 12 per cent of the B.t.u. of the coal burned by the central station.

When the electric furnace or oven is used for drawing at lower temperatures, its efficiency may easily be above 80 per cent, and therefore for this lower temperature process the electric heat shows very much greater economy than the smithy forge.

In passing from the smithy forge to the more modern type of furnace, it may be interesting to study some efficiencies which may be secured in the consumption of fuel by the direct burning process, that is, utilizing it directly in the furnace in which the material is to be treated, and, on the other hand, burning it under the central station boiler and finally heating the furnace by electric heat properly applied.

The accompanying charts illustrate what may be accomplished in this way, contrasting electricity produced by the central station burning coal, and the oil furnace, burning oil directly in the furnace in which material is being heat treated.

Fig. 1 shows graphically the B.t.u. costs for electric furnace versus oil-fired furnace operation for heat treating. The upper large square shows the 20,000 B.t.u. which may be purchased with oil at 7 cents per gallon. With an oil furnace having an effi-

ciency of 16 per cent, which is better than the average, we may expect to put 3400 B.t.u. of the 20,000 into the charge. With

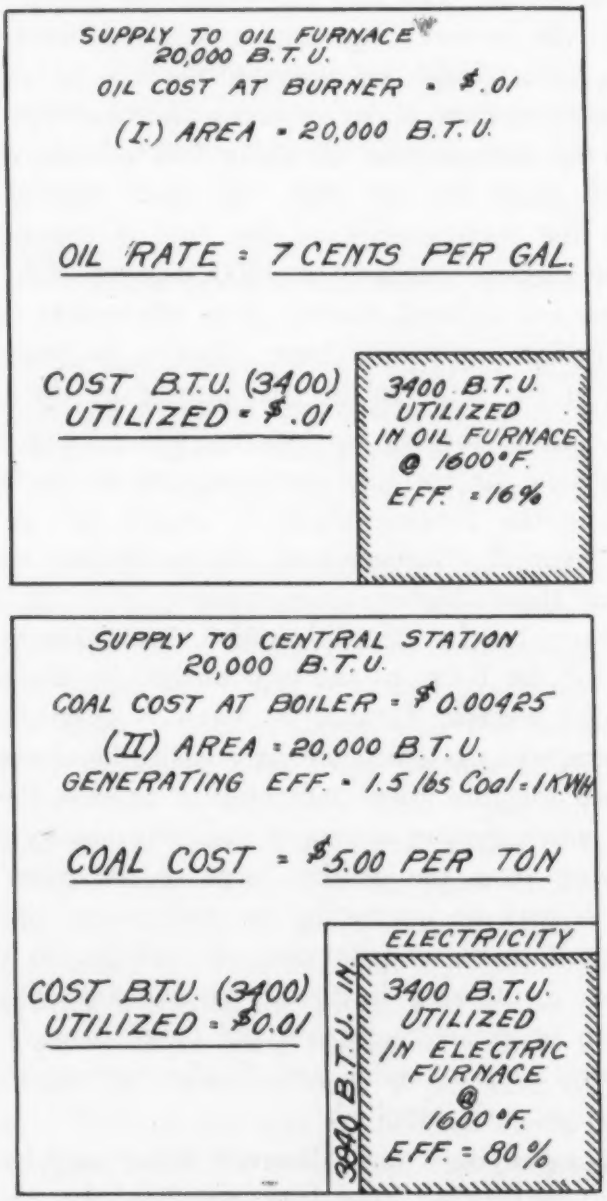
SUPPLY TO OIL FURNACE
20,000 B.T.U.
OIL COST AT BURNER = $.01
(I.) AREA = 20,000 B.T.U.
OIL RATE = 7 CENTS PER GAL.
COST B.T.U. (3400) UTILIZED = $.01
3400 B.T.U. UTILIZED IN OIL FURNACE @ 1600°F. EFF. = 16%
SUPPLY TO CENTRAL STATION
20,000 B.T.U.
COAL COST AT BOILER = $0.00425
(II) AREA = 20,000 B.T.U.
GENERATING EFF. = 1.5 lbs Coal = 1 KWH
COAL COST = $5.00 PER TON
COST B.T.U. (3400) UTILIZED = $0.01
3400 B.T.U. IN
ELECTRICITY
3400 B.T.U. UTILIZED IN ELECTRIC FURNACE @ 1600°F. EFF. = 80%

Fig. 1.—Chart Showing Equal B.t.u. Costs for Electric versus Oil-fired Heat Treating Furnaces at 1600 degrees Fahr. Area 1 is Drawn for 7 cent per gallon Oil, Burned in the Oil-fired Furnace Direct. Area II is Drawn for $5.00 per ton Coal, Used by the Central Station Producing Electricity which in Turn is Used to Heat the Electric Furnace.

coal at $5 per ton, (lower large square, Fig. 1) we may expect from the central station to get 1 kilowatt hour from 1½ pounds

of coal costing 0.425 cents. Adding the overhead charges of the central station we should get about 3840 B.t.u. in electricity for 1 cent. If we use this electricity in the electric furnace with 80 per cent efficiency, we will utilize in heating the charge 3400 B.t.u. In other words, if we get oil for 7 cents at the burner and coal for $5 at the boiler, we just about break even on the B.t.u. cost basis. These figures are for furnace temperatures of about 1600 degrees Fahr.

It is likewise interesting to study the costs for baking enamel at 450 degrees Fahr., Fig. 2, in the electric oven as compared to the cost of the same operation by a process of fuel heating, namely, the "indirect oil" heating method. In this "indirect oil" baking process the oil is burned under or outside of a muffle, air being forced through the muffle and heated to about 800 degrees Fahr. and passed into the japanning oven over the work being baked.

The square B, Fig. 2, represents the 17,000 B.t.u. cost when oil is selling for 8 cents per gallon. The efficiency of the oil heater is 75 per cent and hence 12,800 B.t.u. are sent to the oven in the heated air. The oven efficiency for this method of heating is, by test, 12 per cent. Hence 1540 B.t.u. at a cost of 1 cent, neglecting the overhead cost of burning the oil, are actually effective in heating the charge. Fig. 3 shows graphically the relative cost of the upkeep of the electric oven versus the "indirect oil" system. Hence later on we must correct for this overhead to get comparative costs of electricity versus oil heat.

Referring again to Fig. 2, the bottom square represents 20,000 B.t.u. in the coal at the boiler of the central station costing 0.425 cents with coal at $5 per ton. Assuming average overhead for the central station, the cost of electricity may be taken at 1 cent per kilowatt hour or we get 3840 B.t.u. electricity for 1 cent. Using this 3840 B.t.u. in the electric oven we actually utilize 1540 B.t.u. in heating the charge, at a cost for power of 1 cent. Hence we see that on a B.t.u. basis we may expect to break even on cost when the above conditions exist. These figures have been given to show why the actual test results recorded in Fig. 3 are so greatly different from the 16 to 1 ratio arrived at by offhand reasoning mentioned previously.

It will be seen that actual test results of Fig. 3 are to be

expected after analyzing the problem as per Figs. 1, 2 and 3. It is to be noted for example in Fig. 3 that oil costing 8 cents

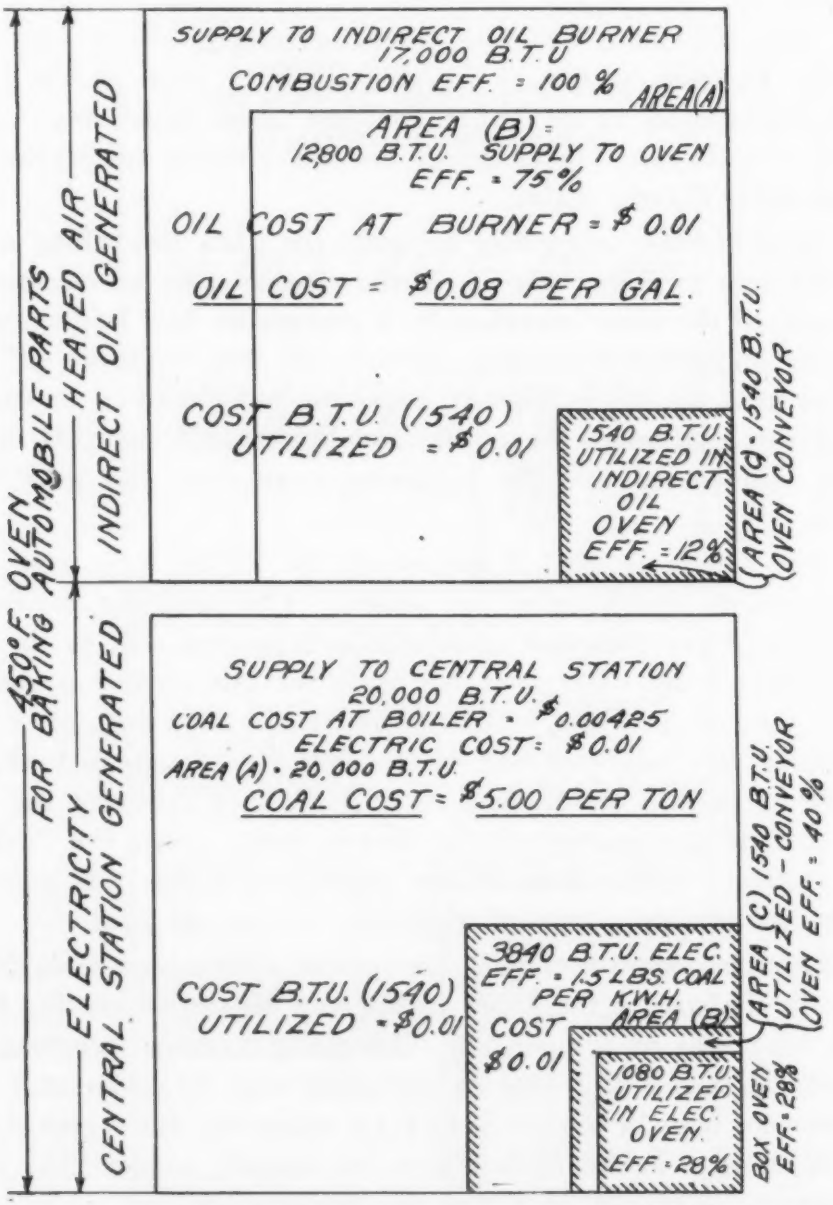
450°F. OVEN FOR BAKING AUTOMOBILE PARTS
HEATED AIR
INDIRECT OIL GENERATED
ELECTRICITY
CENTRAL STATION GENERATED
SUPPLY TO INDIRECT OIL BURNER 17,000 B.T.U
COMBUSTION EFF. = 100 %
AREA(A)
AREA (B) = 12,800 B.T.U. SUPPLY TO OVEN EFF. = 75%
OIL COST AT BURNER = $ 0.01
OIL COST = $0.08 PER GAL.
COST B.T.U. (1540) UTILIZED = $0.01
1540 B.T.U. UTILIZED IN INDIRECT OIL OVEN EFF. = 12%
AREA (C) 1540 B.T.U. OVEN CONVEYOR
SUPPLY TO CENTRAL STATION 20,000 B.T.U.
COAL COST AT BOILER = $0.00425
ELECTRIC COST = $0.01
AREA (A) = 20,000 B.T.U.
COAL COST = $5.00 PER TON
3840 B.T.U. ELEC. EFF. = 1.5 LBS. COAL PER K.W.H.
COST B.T.U. (1540) UTILIZED = $0.01
COST $0.01
AREA (B)
1080 B.T.U. UTILIZED IN ELEC. OVEN. EFF. = 28%
BOX OVEN EFF. = 28%
AREA (C) 1540 B.T.U. UTILIZED - CONVEYOR OVEN EFF. = 40 %

Fig. 2.—Chart Showing Equal B.t.u. Costs for Electric versus Indirect Oil Heated Ovens, Baking Enamel at 450 degrees Fahr.
Note:—Electric Heat Costs equals the Indirect Oil Heat. When Central Station Coal Costs $5.00 per ton and when Fuel Oil (140,000 B.t.u.) Costs 8 cents per gallon (at burner) these conditions hold.

at the burner gives the same over-all cost on the B.t.u. basis that electricity at 1 per cent per kilowatt hour gives for heating a charge at 450 degrees Fahr.

It must not be forgotten then that the efficient generation and utilization of a heat unit is usually quite different for the electric and fuel-fired furnace, when we start with the B.t.u. in the fuel used in the furnace and under the boiler. It must be re-

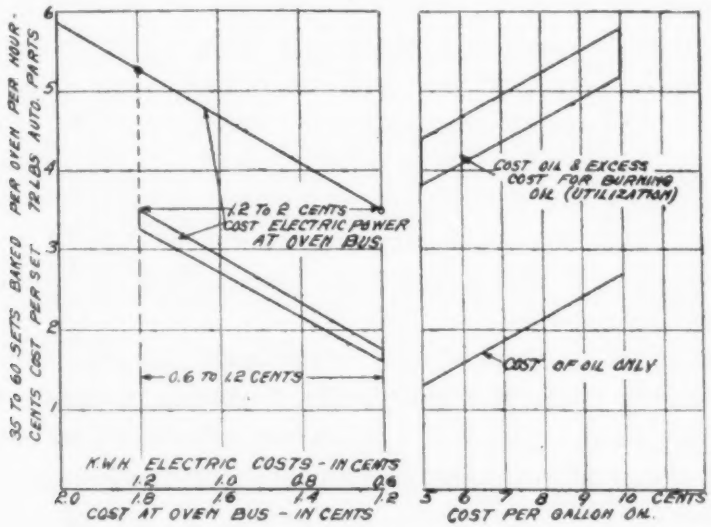
35 TO 60 SETS BAKED PER OVEN PER HOUR-
72 LBS AUTO PARTS
CENTS COST PER SET
1.2 TO 2 CENTS
COST ELECTRIC POWER
AT OVEN BUS
0.6 TO 1.2 CENTS
COST OIL & EXCESS
COST FOR BURNING
OIL (UTILIZATION)
COST OF OIL ONLY
K.W.H. ELECTRIC COSTS - IN CENTS
1.2 1.0 0.8 0.6
2.0 1.8 1.6 1.4 1.2
COST AT OVEN BUS - IN CENTS
5 6 7 8 9 10 CENTS
COST PER GALLON OIL

Fig. 3.—Cost Curves for Baking Enamel (450 degrees Fahr.) in Continuous Conveyor Oven—Electric Heat versus Indirect Oil Heat. This is for 8-Hour Day Operation.

membered that even with perfect combustion of fuel, which seldom exists, that a large percentage of generated heat leaves the metallurgical furnace as flue gas, without doing useful work. In practice 50 per cent excess air is not unusual, and this increases flue gas losses and lowers combustion efficiency to a very remarkable degree as we pass from low to high temperatures.

While these illustrations show that there is a field for electric heat with present day relative costs between fuel and electric heat, it is not intended here to contend that electric heat under all conditions and in all places is suited to replace fuel heating. It is believed, however, that it is only a matter of a short time when the use of electric heat for important thermal and metallurgical processes will be adopted with no more hesitation than now occurs when the householder decides in favor of the electric light for his home as against the gas lamp, even though the cost of current consumed is greater than the gas.

The production manager or executive cares little what the

cost per B.t.u. for a given process is, so long as his over-all cost of manufacture, quality of product and working conditions are unaffected. As a matter of fact if process conditions, quality of product and production were increased by using electric heat, he would be justified in accepting generally a higher B.t.u. cost for the sake of securing these advantages. Fortunately, for the electric heat many such advantages are inherent in its use. These will, of course, vary with the application and local conditions surrounding it. Hence a study of all factors involved should be made before deciding whether electric heat or fuel heat should be used. That these factors are of extreme importance is proven by the fact that industrial electric heating is rapidly increasing in the face of the widespread misunderstanding as noted in the first part of this paper.

Many times a single factor contributes savings sufficient to overbalance any possible higher cost of electric energy. In some extraordinary cases, rates of 75 cents per kilowatt hour would still leave the electrically heated equipment economically superior to the fuel-fired.

Perfect Heat Generation

It should be noted that the cost of burning fuels varies widely, depending upon the amount of air admitted to the furnace and the resultant combustion, e. g., the cost of city gas for 100,000 B.t.u. effective rises to double its value with an increase of 50 per cent in air, and such excess percentage of air is by no means rare. Fuel oil likewise increases its cost roughly four times at the same temperature (2800 degrees Fahr.) and the same excess of air (50 per cent). Hence it is seen to how great an extent the economic operation of the fuel furnace is in the hands of the operator. This handicap does not exist with the electric furnace, where the ratio of conversion from power to heat is 100 per cent perfect, and the operator cannot affect this efficiency of conversion even if he so desired.

A brief outline and summary of some of the more important features of electric heating which distinguish it from fuel-fired equipment may be given as follows:

(1) Heat Generation

a. Released at points to give uniform or nonuniform temperature

b. Heat generation balanced against heat absorption
c. Heat generated at or near potential of heating chamber.
d. Generated in inactive or dead atmosphere—no contamination of charge. Heating chamber may be a vacuum or under heavy pressure. Artificial atmosphere possible as hydrogen gas, nitrogen gas, and no combustion gases.

(2) Heat Conservation Resulting in High Thermal Efficiency

a. High heat lagging, no local high temperatures
b. Small heating chamber and no combustion chamber
c. No hot gases leaving furnace, save for ventilation when necessary
d. Automatic control of temperature so that supply balances demand.

(3) Method of Electric Heat Transmission and Delivery to Charge

a. Convection of liquids and gases (natural)
b. Circulation of liquids and gases (forced)
c. Radiation and convection in air
d. Direct radiation to work
e. Direct and reflected radiation to work
f. Heat generated directly in charge by current flowing through it
g. Complete heat saturation of charge without surface overheating, due to perfect automatic heat control.

Heat Generation in Electric and Fuel Fired Furnaces

In the electric furnace, heat generation can be kept nicely balanced against heat absorption by the charge. The importance of this fact cannot be overemphasized, since the problem of heat absorption is of first importance in all heating, and especially combustion furnaces. Efficient generation or development of heat units by chemical oxidation means little, unless the B.t.u. released are in a minimum constant proportion to the B.t.u. absorbed in doing useful work. Hence the rate of heat generation and heat absorption must be skillfully controlled to guarantee maximum overall efficiency.

To burn fuel correctly is, therefore, only the first step that

has an immediate bearing upon practical results, and this fundamental truth should be recognized by all furnace users. All B.t.u. that fail to be absorbed by the charge are simply wasted, no matter how efficient the burners and resultant combustion may be, and in this lies a definite handicap if the rate of generation to the rate of absorption is not properly governed.

Heat Transmission Regulated by Charge

Heat may be likened to a liquid, which tends to flow as does water, from a higher level or potential to a lower. This flow is resisted more or less, depending upon its method of travel from one place to another. It travels by three different means, namely, (1) convection, in liquids or gases, (2) by conduction in liquids or solids, and (3) by radiation through space or the ether.

When non-uniform heating occurs for any reason, or from any source at different points in a fluid, uniformity of heating may or may not be established due to convected currents set up in the fluid, due to difference in specific gravity resulting from the difference in temperature. Thus, heat itself may establish and furnish the motive power for propelling currents of fluid, which in turn carry and distribute heat throughout the body of the fluid, or other forces may act to set the fluid in motion and thus distribute the heat. In the first case, gravity determines the direction of currents, whereas, in the second, currents may be made to travel more or less as desired. Hence in general, uniformity of heating by convection is made more certain by the second method or by continuous agitation of the fluid (usually mechanically.)

If the fluid be the product of combustion, as in a fuel-fired furnace consisting largely of CO_2, water vapor and nitrogen, then currents and eddies exist in the combustion chamber, due to changes in densities depending in part on variation in temperature. These gases have a continuous flow, and practical results are obtained by removing as much heat as possible from such streams while they are passing through the furnace to the stack. This aim is accomplished more or less satisfactorily by furnace designs which allow the charge to be uniformly swept and enveloped to the maximum by the stream of hot gases.

Complete and properly regulated envelopment is necessary to a uniform and high rate of heat absorption, which is dependent upon heat conductivity of the charge and the area of surface contact. If only parts of the body lie in the stream or if the streams vary in velocity or temperature, we may expect non-uniform heating of that body. It should be remembered that in fuel-fired furnaces, especially where forced draught is used, that these currents of hot gases have a cyclonic violence and continuously shift as erratically.

Convected versus Radiant Heat

Convected heat is deposited at the surface of the body being heated. If the body is a solid, then this heat must penetrate that body by thermal conduction. Radiant heat, such as may be employed in the electric furnace, almost exclusively, has a penetrating characteristic that enables it to pass directly into the charge more or less without being deposited on the surface, as happens with the convected hot gases of the fuel furnace. This results in a more rapid heating and a better or more complete penetration or distribution through the charge without excessive surface heating.

Heat Insulation—Its Importance in Electric and Fuel-Fired Furnaces

Heat must flow into or through a solid against a certain resistance which is called "the thermic resistance" of the body. As in electricity we call low resistance materials "conductors" and high resistance materials "insulators," so in the thermal circuit we call materials of low thermal ohms per unit length and cross section, "conductors of heat," while those of high thermal ohms per unit length and cross section are known as "insulators of heat" or "thermal insulators." Some heat insulators may be injured by low temperatures, while others may be subjected to high temperatures without injury to them mechanically or otherwise. The latter class of heat insulators are usually called "heat insulating refractories." Certain refractory materials are also exceptionally good heat conductors. Many good heat insulating refractories

at moderate temperatures become relatively good heat conductors when heated to a considerably higher temperature. In other words, many heat insulating refractories possess a high thermal resistance when cold and a very low thermal resistance when hot. Hence the furnace designer must discriminate and select proper heat insulating materials.

Knowing the thermal resistance of heat refractories and heat insulators, we may calculate the heat which will flow into or through such a material under any assumed difference in temperature or thermal potential, as follows:

$$\text{Heat quantity in B.t.u.} = \frac{\text{Thermal Potential Difference}}{\text{Thermal Ohms}}$$

Such method allows the selection of proper materials and its proper combination to form a simple or composite furnace wall construction suited to withstand desired temperatures with a heat leakage through the walls which may be calculated with all the accuracy that practical considerations require.

The insulation of heat in the electric furnace becomes important because with high heat insulation and perfect conversion of heat, the "stand by" loss on the electric furnace becomes a fixed minimum for any temperature and constantly corresponds to a definite input of electric power, independent of the operator. Hence the performance of the electric furnace may be definitely and accurately predicted for any load. Due, however, to the variable combustion efficiency of the fuel-fired furnace, uniform performance and thermal efficiency is at the mercy of the furnace operator, fuel and air supply.

Many successful working installations of electric heat exist today, and it is predicted that many more industrial processes will be improved and made more economically productive by the application of electrically generated heat. A considerable demand comes from manufacturers of automobile parts, such as gears, crankshafts, bearings, axles, etc., which are produced in large quantities, and all of which require heat treatment. Many tons of steel are heat-treated each day; therefore the demand for furnaces of large productive capacity and high efficiency.

Electric furnaces have long been recognized as ideal for this purpose, but until the last few years they have not been avail-

able in such size and of such rugged design that they could be considered for carrying unassisted the regular production load. Numerous manufacturers now appreciate the possibilities of the industrial electric heating field and are making installations at an increasing rate. Equipment is available in practically all capacities for temperatures up to and including 1800 degrees Fahr. and suitable for many industrial processes.

A type of metallic resistor furnace entered the industrial field in 1917 and 1918, and its use has been attended with unusual success in regular manufacturing production. It was first tested under the rigorous conditions attending gun-making in war time, and the results produced were phenomenal.

A basic idea incorporated in the design is the location of the resistor ribbon, unmuffled, in the open heating chamber so that it can directly radiate the heat generated within it. These ribbons are very rugged mechanically. Their dimensions are sometimes as great as 1½ inches in width by ⅛-inch thick and are formed into loops. They are supported on refractory insulating members projecting from the walls of the heating chamber, the body portion of the support being imbedded in the wall.

The resistor is thus free to deliver its heat by radiation to the charge without the necessity of first forcing the heat through the walls of a muffle, as has been the practice in most metal resistance furnaces heretofore constructed. In order to force heat through a muffle at a high rate and secure rapid heating of the charge, a high temperature gradient, and therefore a high resistor temperature is necessary. Hence the unmuffled furnace has inherently a lower temperature resistor, produces quicker heating, and is much less sluggish in point of temperature regulation than the muffled or screened furnace doing the same work. The unmuffled furnace uses direct and reflected radiant heat.

A very complete set of tests run on an electric furnace installation of the metallic resistor type of furnace gave results which may be summarized as follows:

Heating to 1450 degrees Fahr. Furnaces hot when charged. Furnaces 6 feet in diameter by 24 feet high, using a voltage of 440, 60 cycles, and a capacity of 400 kilowatts, were charged when hot, being at a temperature of 1450 degrees Fahr.

Charge	Total Weight Including Holding Fixtures	Energy in Kilowatt Hours
Twelve 3-in. gun tubes	21,900 lbs.	1874
Seven 4-in. gun tubes	22,300 lbs.	1880
Three 4-in. jackets	21,700 lbs.	2088
Total	65,900 lbs.	5842

$$\text{Average pounds per kilowatt hour } \frac{65{,}900}{5842} = 11.25$$

$$\text{Kilowatt hours per ton } \frac{2000}{11.25} = 173$$

Energy cost per ton at \$0.0085 per kilowatt hour = \$1.52

This shows what may be done with the electric furnace in moderate scale operations. The time required to heat these charges was 5½ to 6 hours, and the maximum diameter of forgings was 16½ inches. The furnaces were 24 feet high by 6 feet in diameter inside dimensions, the connected load being 400 kilowatts each. The ultimate or minimum radiation from test was found to be 70 kilowatts. The predicted radiation from design was 75 kilowatts, a satisfactorily close agreement.

The actual operating results for four furnaces for the month of October, 1918, when production was at the maximum rate, including both hardening at 1450 degrees Fahr. and drawing at 1150 degrees Fahr., was \$2.76 per ton based on the power rate of \$0.0085 per kilowatt hour.

The specifications for drawing did not allow the charge to enter a furnace at full drawing temperature. It was, therefore, necessary to cool the furnace somewhat, and then raise the temperature of the furnace as well as charge. It was also required that the charge be held at the drawing temperature for several hours. This, of course, did not permit of the highest efficiency in pounds of metal heated per kilowatt hour.

If work at 250 degrees Fahr., to be drawn at 1100 degrees Fahr. enters a furnace at 1100 degrees Fahr. a yield of approximately 24 pounds per kilowatt hour would be realized. This

would give:

$$\frac{2000}{24} = 84 \text{ kilowatt hour per ton for drawing to } 1100^\circ \text{ F.}$$

Therefore, the overall operation required for hardening was 178 kilowatt hour per ton for heating to 1450 degrees Fahr. and for drawing was 84 kilowatt hour per ton for heating to 1100 degrees Fahr., making a total of 262 kilowatt hour per ton.

The cost of $0.0085 per kilowatt is $2.23 per ton. The cost of $2.76 per ton actually achieved during the month of October, 1918, indicates that the furnaces performed exceptionally well.

Tool Room Furnaces

There are many small installations, the importance of which to many shops cannot be overlooked. There is a large growing demand for small self-contained toolroom furnaces for hardening and tempering tools, cutters, etc., and the electric resistor furnace is suited to any heating requirements where the charge does not require more than 1800 degrees Fahr. Some of its advantages over fuel-fired unmuffled furnaces are: (1) radiant heat, (2) satisfactory heat distribution, (3) automatic control of temperatures if desired, (4) small amount of heat given off to the room, (5) no products of combustion or obnoxious gases given off to heating chamber or room, (6) ration of heat generation to heat absorption by charge correctly maintained, (7) uniform and complete penetration of heat through charge without overheating of corners, fins or surfaces, (8) ability to repeat desired heat cycles giving uniformity of product, (9) a reduction, generally, in labor, (10) a better over-all economy and the production of higher quality product at the same or slightly higher cost and often the same quality at a lesser over-all cost.

It is not to be inferred that electric heat is without a competitor in all places and under all conditions. There are, however, a very great number of applications which may show electric heating to be an advantage. These applications in various processes occur with so great frequency that it behooves the user of furnaces to thoroughly question his engineer concerning the possibilities of electric heating before revamping existing installations or adding new heating equipment which employs fuel-fired heating methods.

AUTOMOBILE SHEET STEEL SPECIFICATIONS

By H. M. Williams

Abstract

This paper presents some of the salient factors in connection with the chemical and physical specifications and inspection of sheet steel for automotive and other similar industrial purposes.

The author indicates that it is important that the full co-operation of both the mills and users be attained in arriving at standard specifications. The paper discusses in some detail, factors such as surface finishes, tempers, ability of the sheet to form, and its mechanical drawing capacity.

The author presents the tentative specifications of the General Motors Co. on cold rolled strip steel and sheet steel. These specifications include the physical and chemical tests applied to these materials.

THE development of specifications for the inspection and test of automobile sheets is occupying the attention of many metallurgists and engineers. The demand for this class of steel has at least equaled the supply, and this situation has been a large factor in the postponement of standardization of this important automotive structural material. Very great losses in unusable stampings and in labor to repair defective ones have resulted from faulty or unsuitable material, difficult forms and improper die construction. Frequently, a new die will not produce a perfect stamping for weeks after it is put into commission. Body engineers design parts that are very difficult to develop and the die engineer is not consulted until the design has been approved. It is then a question of finding a quality of sheet that will produce the desired part in a certain die; which often makes it necessary for some sheet mill to produce a new quality of sheet. At the present time, one sheet mill is producing over fifty different kinds of sheets varying in surface finish and temper. It is evident that this condition of affairs results in a great economic loss

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to both producers and consumers. Only the full co-operation of the sheet mills and the automotive body and parts makers can remedy this condition and standardize sheets, design and die construction.

The logical procedure as a first step in the development of specifications, is to standardize on a few sheets representing the surface finishes required for the various methods of finishing; then produce these sheets in a limited number of tempers. Temper refers to the ability of the sheet to form, such as is indicated by deep drawing, extra deep drawing, etc., and not to the carbon or alloy content of the sheet. Die construction must permit of sufficient adjustment to correct for permissible leeway in the physical properties of each temper. Whenever a new part is to be produced, the steel can be readily selected first from the standpoint of finish and then the temper selected by actual tryout of sheets. A standard nomenclature will eliminate many trade names that have been given to sheets by the manufacturers; the same name often referring to sheets of different characteristics if produced by different mills. If such a classification could be made, every one interested would soon be familiar with surface finish and temper, and sheets could be readily substituted, from plant to plant, or job to job.

The question of gage of sheets should have consideration. Instead of using gage numbers, the thickness should be specified in thousandths of an inch, with permissible tolerances within reasonable limits. The only legal gage is the United States Standard Gage for Sheet and Plate Iron and Steel established by act of congress in 1893. This is a weight gage, thickness being incidental. This gage is based upon the weight in avoirdupois ounces per square foot; the thicknesses as established from this gage are approximate equivalents based upon the weight for wrought iron of 480 pounds per cubic foot. Since this gage was established, wrought iron has almost entirely been superseded by steel with a weight of 489.6 pounds per cubic foot. It is thus apparent that there is no satisfactory standard gage for sheet steel. The mills prefer to roll steel to decimal rather than to gage numbers. The thickness of sheets is very important on account of its effect in the dies; before the stampings can be made, it is

quite often necessary for the sheet metal departments to separate the sheets into piles according to their thicknesses. The thickness tolerances on the sheets are very often greater than can be taken care of by the dies without considerable adjustment.

The difficulties encountered in the production and utilization of sheets are numerous and varied. One of the sheet mills has a standard form or data sheet which analyzes rejections of pickled sheets. On this form, six defects are chargeable to sheet bars, seventeen to hot rolling, four to pickling, eight to cold rolling and three to annealing, making a grand total of thirty-eight causes for rejection. Even after a sheet successfully passes this ordeal, it may give trouble in the stamping operation due to forming qualities, poor surface after forming, pulling coarse, stretcher strains, etc.

Forming qualities are dependent to some extent on the surface finish, and particularly on the temper, which is one of the most difficult properties to determine. Forming qualities are determined by actual tests in the dies, this being the only reliable method. Such indications as color, gloss, bending a corner of the sheet between thumb and finger, doubling entire sheet, bending test samples over on themselves both ways of the grain, tensile strength-elongation, and cupping tests are also used with varying degrees of reliability.

Surface inspection is largely a matter of good judgment. It would pay every inspection department to send a man to the mills and co-operate with the mill inspection. Many times sheets are thrown out at the mill for defects that may be discarded in cutting out the blank from which the stamping is formed. Personal contact and a knowledge of just how certain defects are produced will be very enlightening to any sheet inspector.

Surface inspection is largely a matter of good judgment. all sheet is more or less subject. This defect produces the effect of lines and designs in intaglio and ofttimes is too deep to be removed by grinding. This phenomenon is intimately connected with slip of the individual grains over or past one another. The remedy consists in passing the sheet through cold rolls or a roller leveler. The stampings should be made

as soon as possible after the sheets have been given this treatment; some shops are laid out to pass the sheets through a roller leveler and immediately into the forming press. One authority states that after the sheet is given the roller leveler treatment, it is in a plastic condition which may set in a few hours or over night, and unless the stamping is formed before this set takes place, stretcher strains will be produced the same as before.

Grain size is a very important factor in the forming quality of the sheet. The grain size is governed to a large extent by the amount of rolling and the annealing temperature. This has been pointed out in detail in a number of published articles.

Scale Is Troublesome

Scale is the cause of much trouble as it must be removed before finishing. Scale is also very hard on the dies on account of its abrasive nature. Dies used in forming scaly material are often fitted with replaceable hardened steel inserts, which are renewed when worn. The scale referred to here is heavy scale and should be carefully differentiated from the very light thin scale, or better, oxide, that is purposely produced on high grade sheets. This type of oxide is of microscopic thickness and is not broken away in forming. This oxide assists in preventing the sheets from rusting during transportation and storage. On parts that are finished by enameling it is very important that this oxide is not heavy enough to produce a dull finish.

Seconds

"Seconds" are a source of much dispute. It is customary for the manufacturers to include up to 15 per cent seconds in shipments of high grade auto sheet. These sheets are often a dead loss to the body or parts maker, unless some other stampings are being made which will permit their use. Often the seconds must be used where a cheaper material would have been just as satisfactory.

The sheet steel testing committee of the iron and steel division of the Society of Automotive Engineers have adopted a program for the investigation of automobile sheet steel. The

object is to accumulate data which can later be incorporated into a standard specification. This program provides for the following tests which deal with the determination of forming qualities and temper: Tensile strength and elongation, Olsen cup test, Ericson cup test, Rockwell hardness test, scleroscope hardness, microscopic and macroscopic examination, chemical analyses, and bend test.

In order to establish a standard nomenclature for automobile sheet steels, the General Motors Corporation have adopted a tentative specification based on finish and suitability for forming certain classes of parts. This specification is drawn up with the full co-operation of the sheet mills and represents as full a knowledge as we now have. It will be noted that no attempt has been made to determine temper and forming quality, as no reliable method is as yet available. It is hoped in time, after sufficient data has been collected, that some means of developing standards for temper can be adopted. Cold rolled strip steel tempers have been standardized very satisfactorily on the tensile strength-elongation test; many plants are now buying on this type of specification. The General Motors Corporation tentative specification for automobile sheet steel is offered as a basis for discussion and criticism.

Material Specifications for Automobile Sheet Steel

General

1. These specifications cover Automobile Sheet Steel.
2. These specifications are intended primarily to establish a standard nomenclature for Automobile Sheet Steel.
3. These specifications are not intended to supplant the present method of selecting the proper temper and finish by consultation between the producer and consumer, but seek to establish a closer co-operation between producer and consumer and should be regarded as a means to a common understanding.
4. The temper and finish required will be designated by name and symbol letter; for example specification "Regular—B" covers Automobile Sheet Steel in "Regular" temper and grade "B" finish. Temper and finish are described in detail in paragraphs 9 to 11 inclusive.
5. It is recommended that the temper of Automobile Sheet Steel be selected to give the best forming or drawing qualities for the work in hand.
6. Any special requirements, such as oiling, degree of flatness, etc., shall be specified on the Purchasing Agent's order.

Process

7. Automobile Sheet Steel shall be made by the open hearth or electric furnace process.

Chemical Composition

8. Automobile sheet steel shall conform approximately to the following requirements as to chemical composition:

Carbon	.05 to .15
Manganese	.25 to .50
Phosphorus, max.	.06
Sulphur, max.	.05

Tempers

9. Automobile Sheet Steel shall be furnished in the following tempers:

Regular; Deep Drawing; Extra Deep Drawing.

Finish

10. The surface finish of several grades of automobile sheet steel shall conform to the following requirements.

Grade	Finish	Process	Suitable For
A	Smooth silver, free from oxide.	Full acid pickle with an acid or gas pickle after the last annealing.	Two coat enamel work.
B	Smooth glossy blue edges.	Full acid pickle (Not pickled after final anneal).	Two coat enamel work.
C	Smooth glossy blue edges.	Double pickle.	Three coat enamel work.
D	Smooth semi-gloss.	Double pickle.	Painted bodies. (No sand-blasting).
E	Smooth dull.	Double pickle.	Painted bodies. (Sand blasted before painting).
F	Dull.	Commercial Single pickle sheets.	Any formed sheet metal parts, which do not require the highest finish but do require freedom from scale on account of die wear, such as rocker arm covers, crank pans, dash boards, etc.
G	Dull silver.	Commercial de-oxidized sheets.	Same as "F"; must be sand blasted before painting or enameling. May be substituted in emergency for grade "E" in which case it may require an extra coat of rough stuff.
H	Blue	Unpickled Open or box annealing.	Any sheet metal parts, which do not require high finish and where scale will not cause excessive die wear, such as seat bottoms. seat backs which are covered with upholstering, muffler shells, etc.

11. Automobile sheet steel in grades "A" to "E" inclusive shall be free from surface imperfections on one side, and shall have stamped on this surface the name of mill and heat number. Minor surface imperfections on the reverse side shall not be sufficient cause for rejection.

12. Stretcher strains, pulling coarse and other similar defects developing in the fabricating operations are extremely objectionable in grades "A" to "E" inclusive. The producer shall extend every effort to eliminate these defects.

Permissible Variations

13. The thickness shall be specified in decimals of an inch, and shall not vary from that specified on the Purchasing Agent's orders by more than the following amounts:

Thickness	Permissible Variation	Corresponding Gage No.
.069	.008	15
.061	.007	16
.055	.007	17
.049	.006	18
.043	.006	19
.037	.005	20
.035	.005	21
.031	.005	22
.028	.004	23
.025	.004	24
.021	.004	25

All dimensions in inches. All variations plus or minus.

14. The width and length of Automobile Sheet Steel shall not vary from that specified more than the following amounts:

	Under	Over
Width	0	¼ inch
Length	0	2 per cent

Packing

15. Automobile sheet steel shall be packed in such a manner as to prevent damage in transportation. Grades A to E inclusive shall be shipped with stamped side up.

SECONDARY HARDNESS IN AUSTENITIZED HIGH CHROMIUM STEELS

By Edgar C. Bain

Abstract

This paper consists of a summary of hardness measurements made with the Rockwell hardness tester on four grades of high-carbon, high-chrome steel with a variety of quenches and a series of draws. A few micrographs of the steels at certain characteristic stages in their treatments are included to assist in visualizing the structural changes involved.

It was found that in the case of all the steels a quench from a high temperature produced an austenitic state which was permanent at room temperature and which rendered the steel quite soft. Reheating to temperatures of 900 to 1100 degrees Fahr. martensitized these austenitic steels and restored the hardness to nearly what could be developed in a lower quench. Steels quenched for the maximum hardness (martensitic) gradually softened by drawing up to 700 to 800 degrees Fahr. then more rapidly at higher draws.

The chrome and carbon content of the steels is as follows:

	No. 1	No. 2	No. 3	No. 4
Carbon	2.03	1.82	2.22	1.70
Chromium	1.37	6.09	10.56	15.65
Tungsten	0.95			

In case of steel No. 1 the secondary hardness developed at a lower draw than in the others and in steel No. 4, when quenched entirely austenitic the hardness could not be materially increased by drawing. In none of the specimens could the familiar characteristic martensite of carbon steel be discovered when the hardness was developed by drawing from the austenitized condition.

Sample tools made from these steels in which the secondary hardness had been developed after having been quenched austenitic gave results in cutting speed between that of carbon steel and high-speed steel.

A paper presented before the annual convention of the society, Pittsburgh, October 8-12, 1923. The author, Edgar C. Bain, is research metallurgist, Atlas Steel Corp., Dunkirk, N. Y.

IT HAS been pointed[1] out that the high-chrome steels are more reluctant to carry out their complete transformations upon cooling than carbon steels—this effect being more pronounced the more chromium (and carbon) the steel contains. A rate of cooling which would permit formation of coarse pearlite in a carbon steel will likely form very fine pearlite, or perhaps a sorbitic structure in the chromium steel; a rate of cooling which would produce fine pearlite in the carbon steel will form martensite in the chromium steel and render it very hard. A moderate quench which would produce a hard martensitic carbon steel would render the chromium steel polyhedral in grain structure and give it the softness of austenite. When the chromium content is very high (15 to 17 per cent) even an ordinary air cooling of small bars leaves them with the polyhedral structure, calling to mind Hadfield's manganese steel. It has been pointed out too, that cooling from higher temperatures seems also to lower the temperature at which the transformations take place. This fact explains the ease with which the steel can be quenched and retained in austenitic condition after heating to near the melting point. When the steel is hypereutectoid the further solution of the carbides would tend to increase the reluctance with which the transformation takes place when first heated near the melting point.

Scott[2] has stated that the property of secondary hardness in steel involves primarily the production of austenite by the quench which can subsequently be martensitized by raising the temperature. If the equilibrium temperature for the gamma iron to alpha iron transformation has not been lowered by the alloying elements below the temperature at which the metal has sufficient atomic activity or mobility to permit the transformation, then the steel will in general show a secondary hardness.

In the study[3] of the remarkable secondary hardness of high-speed steel it was demonstrated with assurance that much austenite is retained in the material as quenched from about 2250 degrees Fahr. and that the secondary hardness is, to some extent at least, dependent on the amount of austenite retained, and makes its

1. See Metallography—Metals and Common Alloys, Hoyt p. 373-375.

2. Scott, Howard, Relation of the High Temperature Treatment of High-Speed Steel to Secondary Hardening and Red Hardness. *Transactions* American Society for Steel Treating, June, 1921, p. 511.

3. Bain and Jeffries, High-Speed Steel, the Causes of its Red Hardness, *Iron Age*, Sept. 27, 1923.

appearance as this austenite transforms to alpha iron (and carbide). It was, therefore, attractive to the author to study the nature and the magnitude of the secondary hardness which might be developed in the high chrome-high carbon steels which, too, may be quenched wholly or partially in the austenitic condition. Of particular interest was the temperature at which the release of the austenite retained could be brought about.

The hardness measurements recorded here are Rockwell "C" figures and each figure plotted is the average of four closely agreeing measurements. For each of the four steels the hardness is plotted against a series of quenches showing us the temperature of quench for maximum hardness and the higher temperature at which the metal has the softness of austenite. All of the specimens quenched were given successive draws at increasing temperatures. As the same specimen was again drawn after measuring the Rockwell hardness each time the effect of the reheating is cumulative and, therefore, to duplicate the properties in a single draw it might be necessary to make some allowance for previous heatings. At each drawing temperature the hardness specimens were held for one-half hour. To present the observed effect of drawing temperatures upon the variously quenched specimens graphs are shown herewith for each steel in which Rockwell "C" hardness is plotted as ordinate against drawing temperature. Only characteristic specimens are thus depicted so as to avoid confusion in the charts. It should be noted that the points charted are merely connected by short straight lines which do not necessarily represent what is actually happening at intermediate temperatures; for example, the sharp maximum in hardness which might be inferred for certain drawing temperatures certainly does not exist.

The four alloys chosen for this study are specially prepared steels (of the die steel type) whose analyses are as follows:

	No. 1	No. 2	No. 3	No. 4
Carbon	2.03	1.82	2.22	1.70
Manganese	1.29	.35	.36	.31
Silicon	.41	.32	.50	.37
Chromium	1.37	6.09	10.56	15.65
Tungsten	.95	nil	nil	nil
Nickel	nil	nil	.03	.02
Vanadium	nil	nil	nil	nil
Phosphorus, Sulphur	Less than .025			

Steel No. 1

This steel is characterized by its approximate content of carbon 2.0 per cent, manganese 1.3 per cent, chromium 1.4 per cent and tungsten 1.0 per cent. The complete analysis is shown above. Fig. 1 shows the hardness obtainable by an oil quench at various

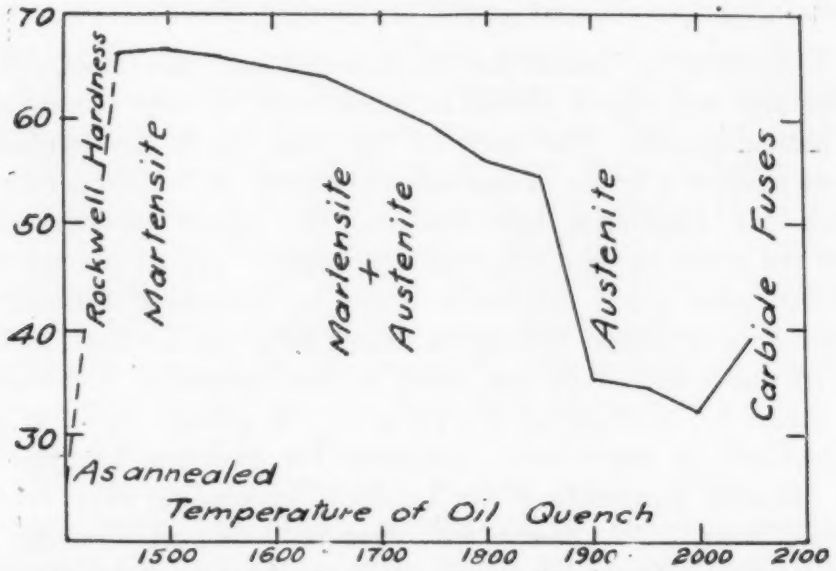

Fig. 1—The Rockwell "C" hardness developed in steel No. 1 by various quenches in oil.

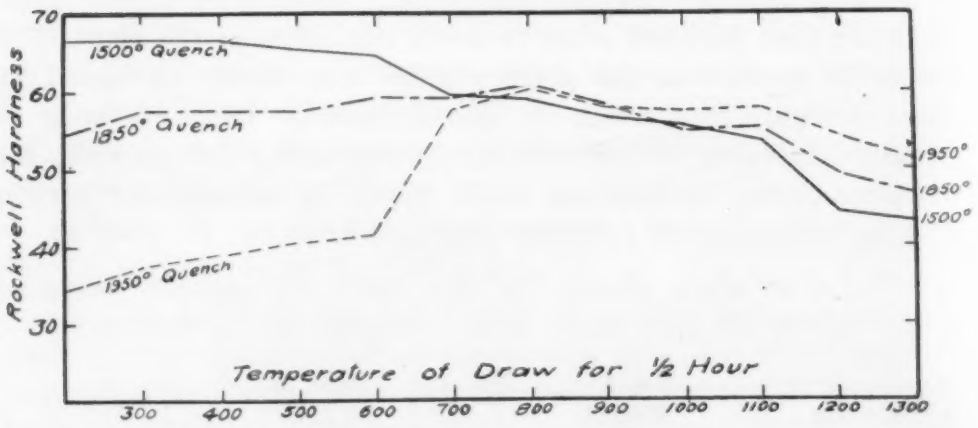

Fig. 2—The Rockwell "C" hardness in three specimens of steel No. 1 quenched from 1500, 1850 and 1950 degrees Fahr. after various reheats.

temperatures. Maximum hardness results from a quench from about 1500 degrees Fahr. and the steel is essentially martensitic with this treatment. A lower quench is somewhat softer due to the solution of less carbide, and a higher quench retains austenite

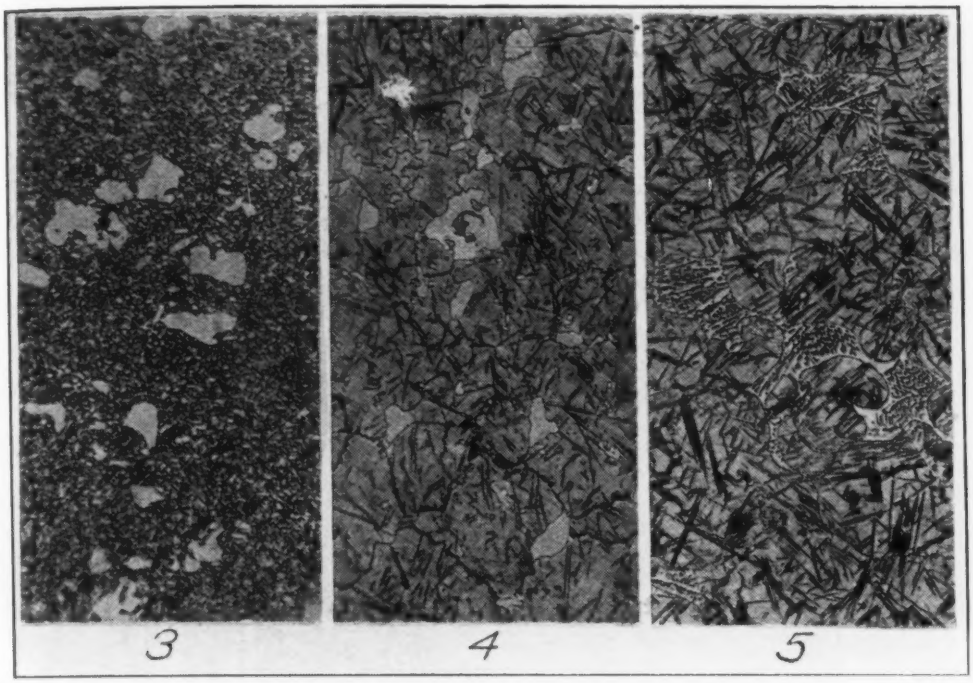

Fig. 3—Microphotograph of steel No. 1 quenched from 1500 degrees Fahr. for maximum hardness. Martensite and undissolved carbide particles. x 250. Fig. 4—Microphotograph of steel No. 1 quenched from 2000 degrees Fahr. for complete austenitization without any carbide fusion. x 250. Fig. 5—Microphotograph of steel No. 1 quenched from 2050 degrees Fahr. after having been slightly overheated. Carbide areas of eutectic appearance. Presence of some martensite. x 250.

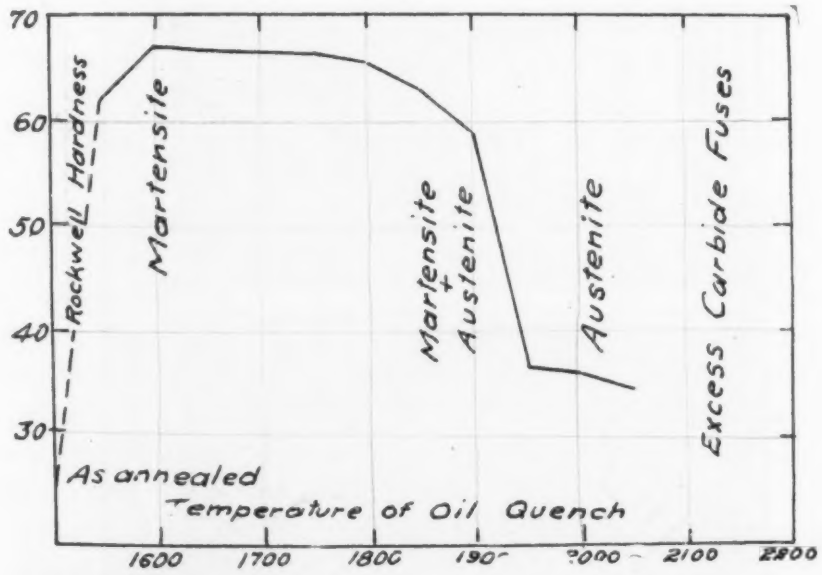

Fig. 6—The Rockwell "C" hardness developed in steel No. 2 by various quenches in oil.

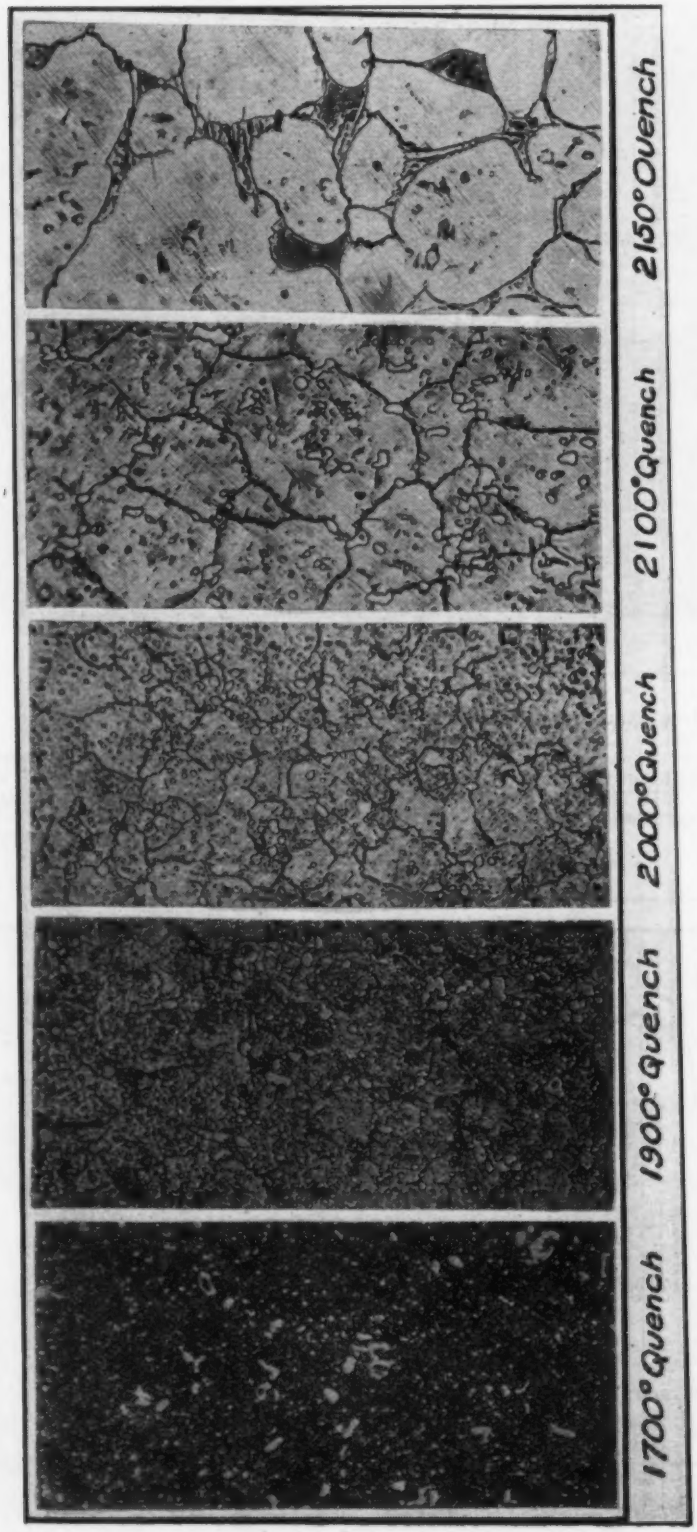

Fig. 7—Microphotographs of steel No. 2 as quenched variously in oil. x 250.

in amount sufficient to soften the aggregate. Fig. 3 is a microphotograph at 250 diameters of the steel as quenched from 1500 degrees Fahr. for maximum hardness. From this photograph it may be seen that the steel is effective in developing great hardness in a structure which lacks the characteristic acicular martensite appearance of carbon steel, but resembles more closely the structure of hardened high-speed steel. The development of acicular or "chevron" figured martensite in this steel is accompanied by the

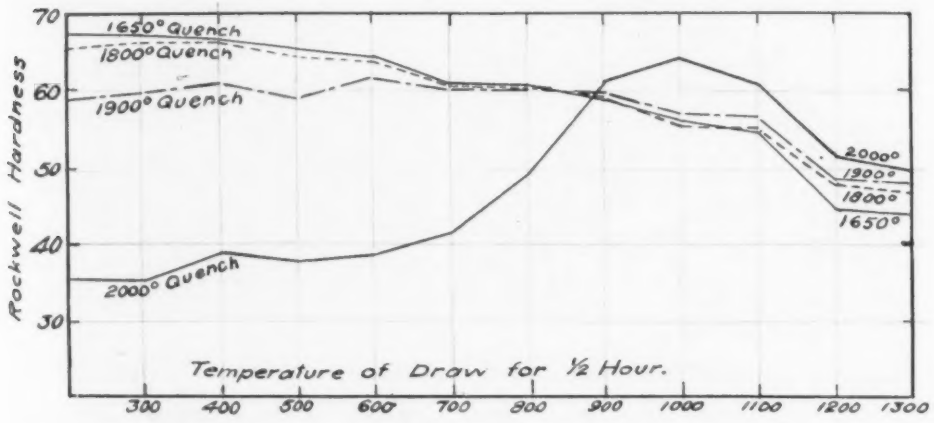

Fig. 8—The Rockwell "C" hardness developed in four specimens of steel No. 2 quenched from 1650, 1800 and 2000 degrees Fahr. after various reheats.

retention of considerable austenite and a softer aggregate than the somewhat troostitic structure of Fig. 3. Fig. 4, at the same magnification as Fig. 3 shows this steel as quenched from 2000 degrees Fahr. to retain it almost wholly austenitic and fairly soft. Even heating this steel 50 degrees Fahr. higher suffices to increase the amount of the carbide regions and give them the eutectic appearance as found in white cast iron. This effect probably marks the temperature of incipient fusion and certainly is accompanied by marked softening in the furnace. Fig. 5 shows the microscopic appearance of the slightly overheated steel after quenching. It can be seen in Fig. 5 that even the quench from 2050 degrees Fahr. does not serve to produce perfectly homogeneous polyhedral grains of austenite but yields some martensite needles within the grains. In Fig. 1, it may be seen that the change in the nature and contour of the carbide regions has sufficed to give a harder material in this highest quench.

The experiments of drawing these quenched pieces revealed the

fact that the austenite retained is transformed into the hard, alpha iron condition when heated a little above 600 degrees Fahr., reaching a maximum in hardness when drawn at about 800 degrees Fahr. This condition of hardness is, however, not so intense as in the material freshly quenched from only 1500 degrees Fahr.

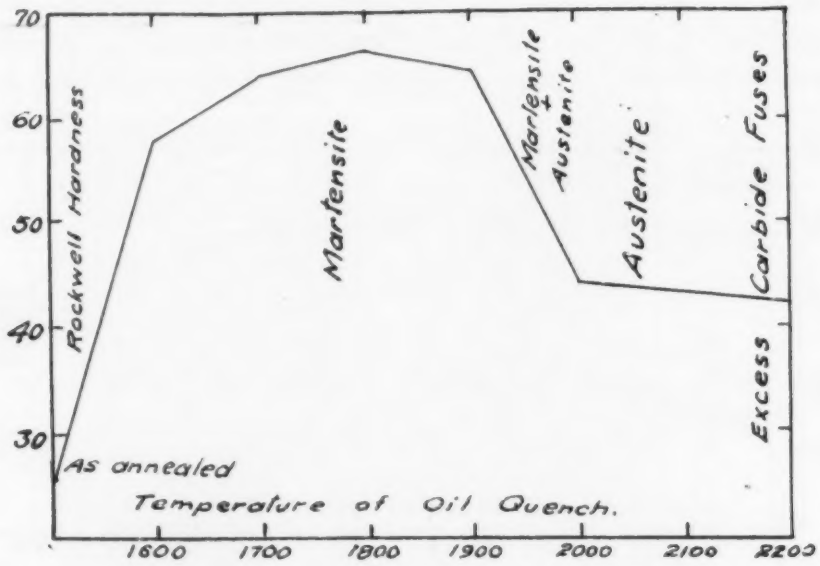

Fig. 9—The Rockwell "C" hardness developed in steel No. 3 by various quenches in oil.

It can be seen from the graph in Fig. 2 that the specimen quenched from 1850 degrees Fahr. contains sufficient austenite to reveal a very decided increase in hardness with heating to 800 degrees Fahr. At above 1100 degrees Fahr. the specimens softened very rapidly, their hardness then being in the order of quenching temperature.

Steel No. 2

An inspection of the analyses given above will show that this steel is characterized by its high-carbon content 1.8 per cent and a chromium content of 6.1 per cent. The hardness curve of Fig. 6 indicates that maximum hardness is secured by a quench from 1600 degrees Fahr. However, it is probable that in general practice the hardest condition is that of a specimen quenched from 1650 or 1700 degrees Fahr. Quenching from 1950 degrees Fahr. or above yields an austenitic steel composed of only polyhedral grains and excess carbide particles. The material when quenched from 1800 to 1900 degrees Fahr. contains martensite in the polyhedral grains.

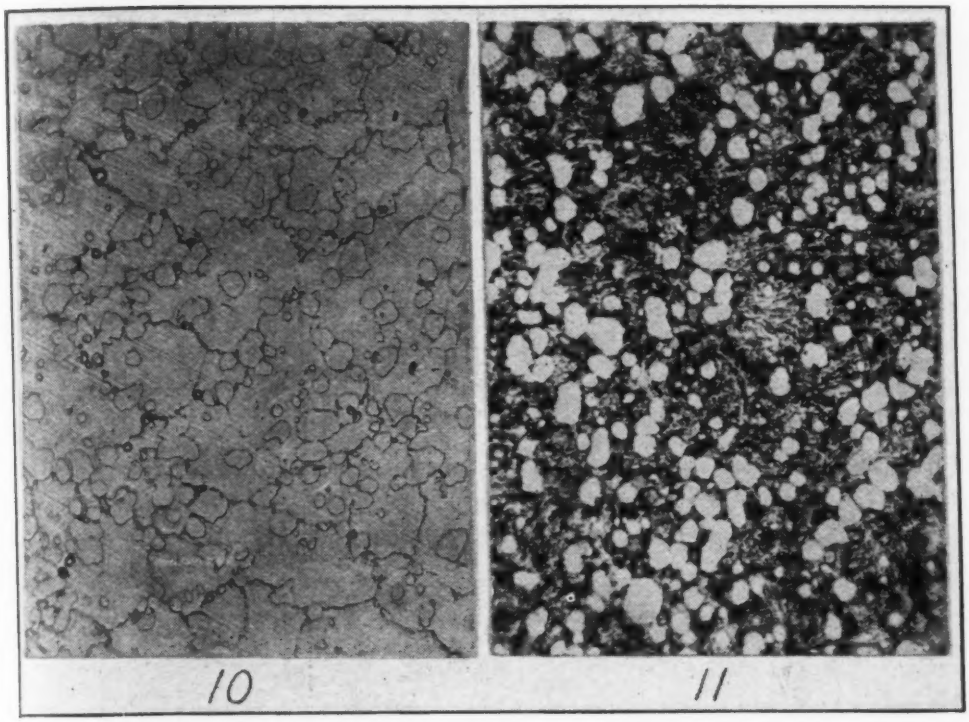

Fig. 10—Microphotograph of steel No. 3 as quenched at 2100 degrees Fahr. for complete austenitization. x 400. Fig. 11—Microphotograph of steel first quenched as shown in Fig. 9 then drawn for maximum secondary hardness.

The series of microphotographs in Fig. 7 show the steel at maximum hardness and successively with greater amounts of austenite obtained by higher quenching up to incipient fusion at the carbide regions.

Attention is called to the grain growth which occurs in the heated austenite in these quenching ranges, and also to the eutectic structure of the carbide in the slightly over-heated specimen which was quenched from 2050 degrees Fahr.

The marked secondary hardness obtainable with this steel is clearly shown by the drawing curve of the specimen quenched from 2000 degrees Fahr. in Fig. 8. In the austenitic condition it has a Rockwell "C" hardness of but 35 while after reheating at 1000 degrees Fahr. it acquires a hardness of 65. Even the quench from 1900 degrees Fahr. does not retain sufficient austenite to show any secondary hardness upon drawing. In some examples of the secondary hardness of this steel the author has found that drawing at 1100 degrees Fahr. develops the greatest hardness which seems

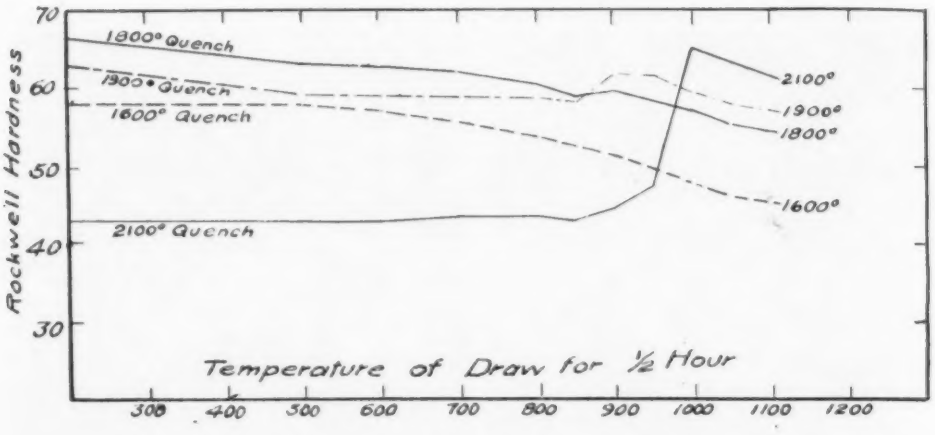

Fig. 12—The Rockwell "C" hardness in four specimens of steel No. 3, quenched from 1600, 1800, 1900, and 2100 degrees Fahr. after various reheats.

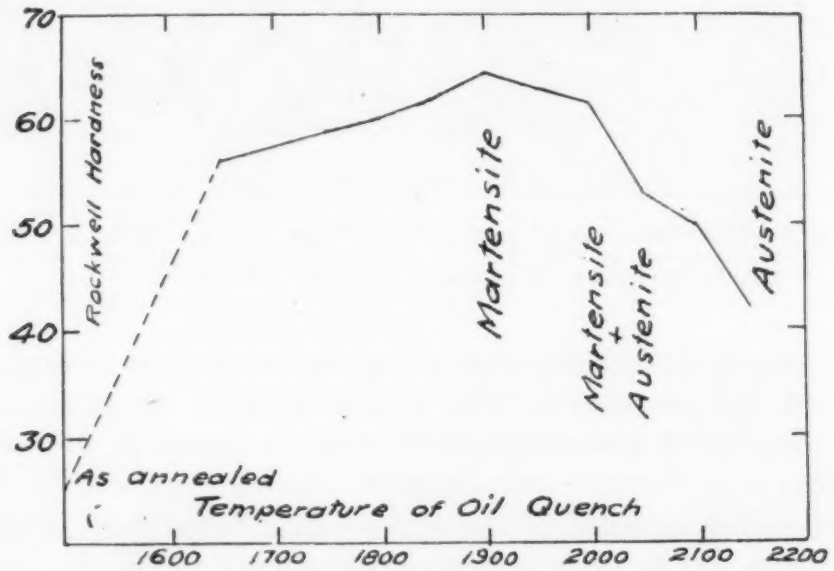

Fig. 13—The Rockwell "C" hardness developed in steel No. 4 by various quenches in oil.

surprising when the amount of softening in hard quenched specimens at this temperature is considered.

Steel No. 3

Steel No. 3 differs from Steel No. 2 mainly in the increased amount of chromium and carbon present, 10.6 and 2.2 per cent, respectively. It is distinctly more hypereutectoid on this account, but also a very hard dense steel. The hardness curve of Fig. 9 shows that maximum hardness results from a quench in oil from

1800 degrees Fahr. and that the steel is essentially austenitic if quenched from above 2000 degrees Fahr. Experiments show that in spite of the added carbon there is a higher softening point, or point of incipient carbide fusion than in Steel No. 2, probably due to the effect of higher chromium content in raising the melting point. The proportion of carbides present can be inferred from the microphotographs of Figs. 10 and 11.

In the chart of Fig. 12 the abrupt and intense development of secondary hardness is shown for the specimens quenched from 2100 degrees Fahr. to produce a wholly austenitic structure as shown in Fig. 10. It will be seen that the polyhedral condition of Steel No. 3 is harder than for Steel No. 2. This may be explained by its much finer grain structure due to the grain-growth inhibition of the copious carbide distribution and also by the direct effect of the undissolved carbide particles acting to discourage slip-plane formation. It will be noticed that the steel quenched from 1900 degrees Fahr. has a marked tendency for secondary hardness, although retaining relatively a small amount of austenite by the quench.

The development of such considerable hardness by drawing at 1000 to 1100 degrees Fahr. in this steel led the writer to suspect that in this condition the steel might have properties resembling high-speed steel. At any rate, a test would certainly show whether great secondary hardness developed at very high drawing temperatures was accompanied by high-temperature hardness. Tools were made for machine work and heat treated as mentioned and tested in the shop. To summarize, the results indicated that while the tool was vastly better than carbon steel in point of speed, and would continue easily to cut fairly hard stock at blue heat, yet it was not comparable with high-speed steel in very severe duty such as machining scaly annealed heavy forgings of high-speed steel. It is predicted that a steel thus treated for a hardness say of 64-65 Rockwell "C" would have a much higher impact strength than one quenched directly for the same hardness or drawn at a low temperature.

Steel No. 4

This steel has lower carbon content (1.70 per cent) than steel No. 3 but somewhat higher chromium (15.6 per cent). The amount of carbide is only a little less than in No. 3. In heating for quenching it was observed that higher temperatures could be

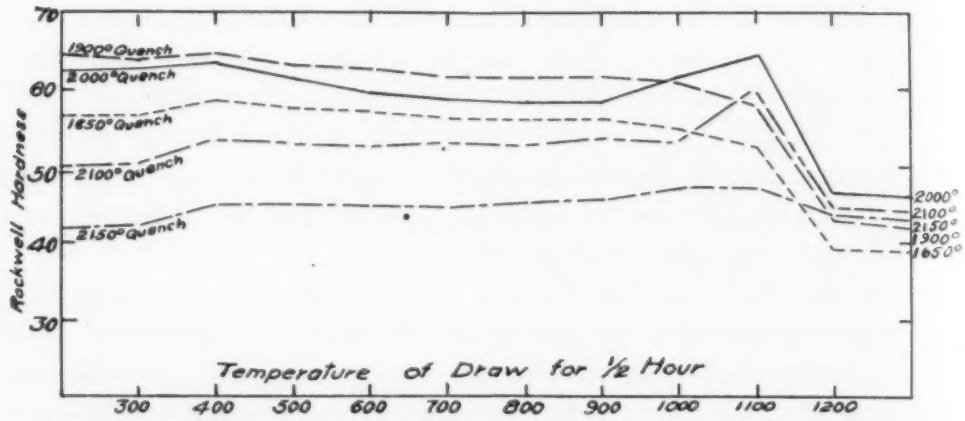

Fig. 14—The Rockwell "C" hardness in five specimens of steel No. 4, quenched from 1650, 1900, 2000, 2100 and 2150 degrees Fahr. after various reheats.

applied without fusion of the carbides than for any of the other steels studied. It reaches maximum hardness when quenched in oil from 1900 degrees Fahr. and can be prepared essentially austenitic by a quench from 2150 degrees Fahr. Fig. 13 shows the hardness developed by various quenches.

The steel is sluggish in action when the quenched specimens are reheated. The steel at maximum quench hardness does not soften rapidly until a temperature of nearly 1000 degrees Fahr. is reached. And when quenched to retain the steel largely as austenite there is very little increase in hardness with drawing temperature even up to 1300 degrees Fahr. Fig. 14 shows that the greatest secondary hardness is derived from the steel when quenched at 2000 degrees Fahr. a temperature only sufficiently high to retain relatively a small amount of austenite. In this respect the steel more closely resembles high-speed steel which shows secondary hardness when quenched partly martensitic. It appears as if the steel requires a few neuclei of iron in the alpha allotropic state (martensite) to start the transformation when reheated.

The following table shows in a condensed manner, the effect of quenches and draws upon the steels.

Steel No.	Temp. for Max. Hardness—Degrees Fahr.	Min. Temp. for Austenite—Degrees Fahr.	Temp. at draw for Max. Sec. Hardness Degrees Fahr.
1	1500	1850	800
2	1650	1950	1000
3	1800	2000	1000
4	1900	2100	1100

It has been the opinion of the author for some time that the

study of the phenomenon of secondary hardness in steels other than high-speed steel has been in a sense overlooked or neglected. The tests which have been recorded here represent the beginning of an investigation to discover if possible whether this treatment may develop properties which may be useful to the industry. In the meantime accurate knowledge of the behavior of the steels undergoing various heat treatments can be gleaned and it may perhaps throw light upon more familiar phenomena.

Discussion of Mr. Bain's Paper

CHAIRMAN BOYLSTON: I would like to ask Mr. Bain whether it is not probable that it is due to the stainless quality of the steel he has been testing, that he has been unable to find a suitable etching agent that will bring out the martensitic acicular structure?

E. C. BAIN: That is a very good question. I contemplated that a long time myself, and I showed no photographs of that last steel because it was so hard to etch it satisfactorily. We tried various etching reagents and some were so powerful that they dissolved the steel rapidly, and those areas still etched smoothly, as we have come to believe that austenite does, particularly in the 11.0 per cent manganese type of austenitic steel. So I think we can be quite sure it was austenite in that case, just like the other.

A. H. d'ARCAMBAL: I would like to ask Mr. Bain what some of these different compositions of steel are used for. Are they for any particular purpose, or are they simply the result of experimental work?

E. C. BAIN: This work was purely experimental. I think some of the steels may have good uses, but two were special heats made up after the general type of die steels.

A. H. d'ARCAMBAL: It was interesting to note that the microstructures obtained on the highly quenched specimens, where austenite was produced, were very similar to high-speed steel, although high-speed steel quenched and not drawn, has only a small percentage of austenite present while this material with apparently the same microstructure, showed nearly 100 per cent austenite, indicating that we know very little about these microconstituents.

E. C. BAIN: The photomicrographs of these steels, when quenched just a little too low to produce all austenite, might deceive almost anyone as being photographs of high-speed steel. They are indeed similar. I believe high-speed steel properly quenched is more than half austenite.

A. H. KINGSBURY: Did you supplement your hardness tests with file tests on the austenitic steels?

E. C. BAIN: I did not, but I am familiar with the deceptive nature of the softness of this kind of austenite, and, as I said, the Rockwell in-

strument is the ideal one to measure this property. If the material is worked, as for instance in a file test, it becomes quite hard, so I suspect that is what you have observed; this hardness is quite deceptive.

A. H. KINGSBURY: The reason I asked that, Mr. Bain, is because I happened to be interested in some experiments with a steel like that of 10.0 per cent chrome and 2.0 per cent carbon some time ago and what appeared to be austenite was produced. We did not have a Rockwell hardness tester available, but other tests showed the steel attained approximately 700 Brinell in the quenched condition, where one would expect to get a so-called martensitic structure from possibly 1800 degrees Fahr. When that same steel was quenched from 2150 degrees Fahr. and the structure examined, it was found to be austenitic or the same as you found in steels of similar composition; the Brinell dropped to 350 and the scleroscope, to about 60, but there was not a file available with which the piece could be touched.

PROF. O. W. ELLIS: Mr. Bain's remarks with regard to an explanation of the phenomenon of secondary hardness were very interesting. He takes as an explanation the widely accepted one, of slip interference. I am prepared to accept that as a partial explanation of the increase in hardness. Suppose, however, that we take a hard material and precipitate a soft substance within it and increase the hardness. I have just recently been performing experiments on Beta brass with the purpose of discovering whether by the precipitation of small particles of Alpha constituent in the quenched Beta brass I could increase the hardness of the Beta brass, and, as a matter of fact, the hardness of Beta brass can be increased by the precipitation of small particles of Alpha by as much as 12.0 per cent. I believe on this account, that the large increase of hardness in the case of steel is due mainly to slip interference, but partly also to the presence of fine particles, that the fine particles themselves have caused some increase in hardness; that there is something beyond and above mere slip interference that can account for the changes.

H. P. HOLLNAGEL: I think the answer to Prof. Ellis' question is to be found in the introduction of stranger atoms in the crystal structure, which in a solid solution, tends to increase the hardness. In the case of "Y" alloys, for example, that has been shown by Rosenheim.

PROF. O. W. ELLIS: I scarcely think it can be explained on the assumption that a stranger atom is present, because when there are visible particles of Alpha constituent present, the hardness is still increased by about 12.0 per cent. It is not until the quenched brass has been reheated for some considerable time that any marked depreciation in hardness is noted. Something larger than a stranger atom must, therefore, be taken into account, in explaining the increase in hardness.

H. P. HOLLNAGEL: It might not necessarily be just the atom itself, but it could well be the interference of a crystal structure of one sort with one of another type. It would not necessarily have to be a random distribution of the atoms, though it is conceivable that this could cause hardening.

I would like to ask Mr. Bain if Mr. deForest's magnetic method of testing hardness might not be a very good scheme for testing hardness in this particular instance. Where he bases his hardness entirely on the austenitic character of the material, it would appear that a magnetic test would indicate to advantage the changes obtained. It would seem that valuable information should be had from this kind of comparative test.

E. C. BAIN: Yes, I think we might get some very interesting information by paralelling these tests with the magnetic test. As I understand it, however, the magnetic test is so sensitive and such a fine tool for measuring changes in state of aggregation that we might find that we were getting differences from the things we are not attempting to control, which would over-shadow those we were attempting to control. We certainly might run into that difficulty. However, I look forward to some very interesting information from that source.

About the solid solution explanation for hardness, etc., we must at all times regard the hardness as coming from three distinct sources; the stranger atom hardness that was spoken of, would operate only noticeably in fairly large sized grains of true solid solutions, such as we have in the austenite grains. This austenite is doubtless harder than pure iron. If we could have pure iron in the Gamma condition at room temperature it would probably be a relatively soft material; as soft as copper, perhaps, certainly as soft as nickel, because the iron atom is quite similar to the nickel atom and is arranged like the nickel atom, but the preserved austenite is not that soft, because of the foreign atoms, chromium and carbon.

When we first quench a steel for martensite we derive hardness from two sources, first, we have produced an extremely fine grained ferrite structure and secondly, we still have our carbon atoms present offering great resistance to distortion, because of their own force distortions.

With these remarks, I propose we leave all of this discussion of hardness to R. S. Archer, who I believe follows me with his splendid work on hardness that I have already read in TRANSACTIONS.

S. L. HOYT: I wish to advance a word of caution here with regard to the naming of the constituent martensite, which is supposed to be responsible for this secondary hardness. I have been pondering over that question for a period of years, as to whether or not martensite forms on reheating, and I must confess that I have not as yet arrived at any definite conclusion.

I have found that on first etching a piece of quenched high-speed steel, the structure appears to be austenite, but that by continuing the etch somewhat longer than would be customary, a typical martensite structure develops.

In observing the curves which were shown here, I note that the hardness,—I am referring to the secondary hardness produced by draw-

ing the austenitic steels,—never quite reached the hardness of the so-called, martensitic steels.

Again, Mr. Bain tells us that he never has noticed the typical acicular structure in the steel which has the secondary hardness, and, as far as I can see, the whole thing is very similar to the behavior of manganese steel on reheating.

I have had occasion, elsewhere, to discuss the changes which take place in manganese steel on heating, and at that time I came to the conclusion that the physical properties, such as hardness and magnetic properties, were to be accounted for on the assumption that the constituent which forms is troostite, and not martensite. Martensite is the name of a constituent which in most circumstances is very well defined, and very well understood, and unless it were to be proved beyond any shadow of a doubt that constituent which is responsible for secondary hardness actually is martensite, I think we are making a grave mistake in this society in calling it anything but troostite. We must bear in mind that our publications are read very extensively, and if we continue to call that constituent martensite, when evidence is certainly not clear that it is martensite, and secondly, when there is considerable evidence or at least opinion that the constituent is troostite, I feel that we are treading on dangerous ground.

E. C. BAIN: I want to thank Dr. Hoyt for his discussion. I purposely mentioned several times that we had not seen anything to indicate that this hard constituent obtained on drawing was martensite.

Since martensite is a structural constituent and not a chemical constituent, I too, think we must stand firmly on that. As a matter of fact, troostite certainly does come closest to fitting the requirements of this material resulting from drawing for hardness.

CHAIRMAN BOYLSTON: Do you infer that when you have the dark acicular crystals present, that they are troostite and not martensite?

E. C. BAIN: No, when they are *not* acicular. I should say we have never obtained the acicular structure on the draw and it conforms, certainly, with our conception of troostite more closely than anything else. I would say this, however, that the final answer on what the constituent is, when freshly quenched from a high temperature, lies with the X-ray examination, and it is a perfect face-centered cubic material, just like that obtained from the specimen while hot, or from any specimen of iron while heated above the critical range, and exactly like manganese steel quenched so as to preserve the softness, and nickel steels too; so there could be no doubt that chromium is a powerful stabilizer of austenite, being the next most effective to manganese. Just one other word. The specimen made hard in this manner, by the high-quench high-draw method, has a great deal higher impact value than specimens of the same hardness in freshly quenched material.

J. S. VANICK: I would just like to ask a question in regard to the basis for the statement that ferrite is precipitated in the very high chromium steels over the tempering range, to explain the maintenance of softness over that range. It seems to me that steel carries such a very large amount of chromium, which retards the reversal of the transformations to such a great extent, that it starts austenitic and stays austenitic over any ordinary tempering range, and I would question the explanation of the maintenance of hardness on the basis of the precipitation of ferrite.

E. C. BAIN: I believe there must be precipitation of ferrite, since ferrite is the only material we know which could gradually increase the magnetism up to the full value of the ferro-magnetism at the end of the draw series. It seems to be the only thing possible which could do that, and I am quite certain that an X-ray examination of these progressive draws would show that the amount of ferrite was progressing continually. I know, it did so in the case of high-speed steel, and I think we can be quite safe in saying it would be the same here, since the magnetism increased progressivly.

J. S. VANICK: Would there be evidence, in X-ray methods of the precipitation of carbides?

E. C. BAIN: Yes, I think there would be; it was so in high-speed steel, and I believe it would be here, although the X-ray fails completely on the carbides of the chrome steels

A. E. BELLIS: Mr. Bain brought up one very interesting, practical point upon which I would like to comment. The point which he brought up and which checks my experience is the usefulness of the Rockwell hardness tester over the ranges of hardness within which he is working. I have done a great deal of work testing the hardness of hardened high-speed steel, and I have found the Rockwell hardness tester very satisfactory in that respect.

CHAIRMAN BOYLSTON: We must reluctantly defer further discussion on this paper, but written discussion, is always acceptable and welcome.

The Question Box

A Column Devoted to the Asking, Answering and Discussing of Practical Questions in Heat Treatment — Members Submitting Answers and Discussions Are Requested to Refer to Serial Numbers of Questions

NEW QUESTIONS

QUESTION NO. 107. *In the hardening of ten thousand small tools, punches and dies weighing between three and ten pounds each what percentage loss due to hardening should be ordinarily expected?*

QUESTION NO. 108. *What are the advantages and disadvantages in the use of the "drop of the beam" method for determining the elastic limit of a steel tensile test bar?*

QUESTION NO. 109 *What are hair-line cracks and how may they be detected?*

QUESTION NO. 110. *Do notched bar impact specimens give more uniformly constant results than an un-notched bar?*

QUESTION NO. 111. *How is the reduction of area of a flat tensile test specimen usually obtained?*

ANSWERS TO OLD QUESTIONS

QUESTION NO. 69. *Is sulphur up to* 0.10 *per cent detrimental to the quality and physical properties of an automotive steel?*

ANSWER. By J. M. Wilson, Philadelphia.

A sulphur content up to 0.10 per cent is detrimental to the quality and physical properties of an automotive steel.

A sulphur content as high as 0.10 per cent increases hot shortness and causes tearing in rolling or forging. If, however, such a metal should be successfully hot-worked, it would be a trifle stronger than the same quality of steel with a sulphur content of 0.05 per cent.

QUESTION NO. 72. What elements are conducive to good electric butt-welding of steels?

ANSWER. By J. R. Dawson, Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y.

The same properties that are conducive to good forge welding are desirable in steels for electric resistance welding. The American Society for Testing Materials Tentative Standards for 1923 may be referred to for information about steels to be forge welded. For best results, these steels should contain less than 0.20 per cent carbon and less than 0.60 per cent manganese. They should preferably be free from silicon, nickel and chromium.

QUESTION NO. 73. Does electric butt-welding destroy the physical properties developed in a steel which has been heat treated prior to the welding operation?

ANSWER. By J. R. Dawson, Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y.

In electric resistance welding, the weld is obtained in steel that has been brought almost to fusion. This high temperature changes the structure and physical qualities materially in the highly heated areas, and to an extent in the neighborhood of the weld, depending on the temperature attained.

QUESTION NO. 74. Why shouldn't a bar of steel rolled from a locomotive axle be better than one rolled direct from the billet made from the original ingot?

QUESTION NO. 83. In annealing high-carbon tool steel in an open-fire furnace 6′ x 12′ is it likely that sulphur would be

imparted to the steel by the use of producer gas made from coal unusually high in sulphur, say around 1.50 *to* 2.00 *per cent?*

ANSWER. By J. M. Wilson, Philadelphia.

Hot steel regardless of its carbon content has a strong affinity not only for sulphur but also for carbon and phosphorus. The writer recalls a case of sulphur absorption in a boiler plate, which on being subjected to a high sulphur coal fire during the rolling process, absorbed 14 points of sulphur over and above the allowable limit for that material. The metal absorption was 50 per cent over the sulphur content of the metal. This absorption penetrated ¼-inch in what finished to be a ⅝-inch plate.

QUESTION NO. 93. *What are the more common methods of quenching ordinary taps? Are they quenched all over and the shanks drawn, or are they quenched only on the threaded portions; or are both the threaded portions and the tangs quenched, leaving the center portion of the shank soft?*

QUESTION NO. 96. *Can the structure of a piece of steel be determined by the microscope applied to the fracture of a cross section, without polishing and etching the fracture, say of a stamping die* 6 *x* 2 *x* 3½ *inches, that has been hardened and broken in half, that is, are the different structural phenomena known as austenite, martensite, sorbite, ferrite, etc., so determinable?*

QUESTION NO. 98. *What heat treatment will give a pure martensite structure throughout the hardened area of a piece of steel* 6 *x* 2 *x* 3½ *inches?*

QUESTION NO. 99. *What is the effect of barium carbonate and sodium carbonate in carburizing compounds, on alloy carburizing boxes?*

QUESTION NO. 100. *What action results from the addition of varying amounts of aluminum and ferrosilicon to steel while casting?*

QUESTION 102. *How can the warping of high-speed steel tools be eliminated during the hardening operation?*

ANSWER. By George C. Davis, Heat Treating Equipment company, Boston, Mass.

The distortion or warping of high-speed steel in heat treating may be explained by the same three basic reasons as usually assigned in explanation of distortion in carbon steel, namely, non-uniform heating, too rapid initial heating and quenching.

Non-uniform heating may best be corrected by the use of a liquid heating medium or heated bath for obvious reasons. This fact has long been recognized and many attempts have been made to develop a liquid suitable for the conditions applying. Recently such a medium has been developed and has shown an ability to accomplish this purpose as well as many other desirable benefits.

Distortion due to too rapid initial heating may be eliminated by controlling the rate of heat penetration and by careful pre-heating. Again a liquid heating medium such as that already referred to is advantageous, since it automatically accomplishes this purpose. This is due to the formation of a film with low heat conductivity over the surface of the bath upon immersion. The thickness of this film and therefore the rate of penetration allowed, is then dependent upon the bulk of the piece and the melting temperature of the medium.

Distortion due to quenching may be caused by improper handling but it has recently been pointed out that the rate of heat flow out of the steel, affects distortion in the reverse of the heating up effect referred to above. The solution, therefore, is a quenching medium which will carry off the heat only just so fast as the steel is able to conduct it through itself to the surface. This is accomplished by many today, by quenching in a heated bath rather than oil or air. If the

proper medium is used, the temperature may be controlled, usually 1100 to 1200 degrees Fahr., so that the piece cools uniformly with a rate of heat extraction equal to the conductivity. Below this temperature the piece may be safely cooled in oil.

QUESTION 103. *What is the effect of clay luting on alloy carburizing boxes?*

ANSWER. By W. E. Blythe, Driver-Harris Co., Detroit.

Due to the wide variation in the composition of clays used for luting carbonizing boxes, it is almost impossible to make a general statement that will hold true for all cases. However, the majority of the luting clays will attack a nickel-chromium carbonizing box around the rim, and the use of such clays is not recommended. With a specially designed box and cover, it has been found that it is entirely unnecessary to use luting clays for sealing the boxes. Such boxes have been used by many of the largest heat treating plants in the country and it has been found that with their use, luting clays are entirely unnecessary.

QUESTION 104. *In the forging of ring gears, does the number of blows of the hammer have any effect upon the warpage of the gear in the hardening operation?*

QUESTION 105. *Through what mechanism does vanadium retard the penetration of hardness in vanadium steels in the hardening operations?*

QUESTION 106. *What are the effects of the products of combustion upon both carbon and high-speed steel, when heat treated in open furnaces heated with city gas, coal, coke, fuel oil, etc?*

NOTES FROM THE U. S. BUREAU OF STANDARDS

Breakdown Tests of High Speed Steel Lathe Tools

PROGRESS was made during the past month on the third series of tests of these steel which is being carried out in co-operation with the metallurgical laboratory of the Naval Gun Factory. The previous two series were reported at the fourth and fifth annual conventions of the A. S. S. T. Two hundred fifty-four so-called "standard" tools have been heat treated. A carbon steel log showing 75,000 pounds per square inch tensile strength has been prepared and is ready for surface machining prior to testing, and in addition some work has been done on the preparation of three nickel-steel test logs with tensile strengths of 75,000, 100,000, and 125,000 pounds per square inch. Further arrangements were made with several steel mills covering various alloy steel blooms to be worked up into test logs, and one of the seven blooms which are to be supplied has already been received. During the past month an examination was likewise made of the results of the "breakdown tests" carried out in the second high speed steel investigation, with the object of representing the results mathematically. It was found that the speed endurance curves for the four commercial types of high speed steels were very closely represented by a relatively simple equation having one constant. Furthermore, this equation fits experimental results published by the Lathe Tools Research committee of the Manchester Association of Engineers which are based upon tests made under entirely different conditions. These calculations and methods will be used in carrying out subsequent tests on the several alloyed steels.

Effect of Severe Cold Rolling of Metals

Some rather striking and unexpected results have been obtained in connection with the Bureau's study of the effect of severe cold rolling on metals. In brief, it has been found that when a metal is deformed by cold rolling it becomes harder, but if the cold deformation is continued without any intermediate annealing, the hardening process continues up to a maximum, after which a reversal occurs and the metal becomes progressively softer. The microstructural changes are also indicative. During the hardening the identity of the crystals can be detected readily although they are distorted more and more by interior "slipping" within the crystals as the deformation increases. When all evidence of crystality as judged by the appearance under the microscope has disappeared, and the grains have been compressed into flat thin "scales," the hardening ceases and with still further deformation, softening occurs. The results so far obtained were presented at the recent meeting of the advisory committee on nonferrous alloys and were very well received and some excellent suggestions for additional work along this line were offered. Additional work now in progress will include a study of the possible directional properties of the rolled

sheets, i. e., a determination of the hardness of the metal on sections perpendicular to the rolled surfaces as well as on the surface itself. The possible effect of the heat generated within the metal during the severe deformation and its relation to the hardening properties will also receive attention. The Bureau plans to study the structural atomic changes of the very severe rolled metals by means of the X-ray crystallographic method as soon as the necessary apparatus is available for use.

Uniform Classification of Iron and Steel Scrap

A conference was held at the Bureau of Standards on November 9 at which the adoption of a uniform master classification for iron and steel scrap was discussed. Representatives of many prominent industrial associations and government departments were present. The meeting was arranged by the Bureau as the result of opinions expressed by many interested groups that such a conference ought to be held. G. C. McClure of the National Association of Purchasing Agents, submitted for consideration a classification drawn up by a subcommittee of that association. This classification includes six major divisions as follows: Specifications covering scrap for use in (1) blast furnaces, (2) basic open-hearth furnaces, (3) acid open-hearth furnaces (this scrap being of low phosphorus and low sulphur content), (4) electric furnaces, (5) gray iron foundries, and (6) bessemer converters. A seventh classification to include scrap for use in the manufacture of wrought iron was considered desirable. It was the concensus of opinion that a national classification should cover the material when broken down ready for the furnace and should not go into details as to the various items composing the scrap. These details should be left to the purchaser's selection, according to his individual requirements. The discussion brought out the fact that much more work will be necessary before the classification can be finally agreed upon. This will be carried out largely through correspondence, the Bureau acting as a clearing house for the exchange of comment and criticism. The tentative classification will be published and circulated among those interested, and when finally agreed upon, will be submitted to the Bureau of Standards for indorsement as a national classification.

Meeting of the Advisory Committee on Nonferrous Metals

The regular autumn meeting of this committee was held at the Bureau of Standards, November 16. The large attendance and excellent discussion of the topics presented made the meeting one of more than usual interest. The discussion covered tentative and proposed specifications for nonferrous metals and alloys, new standard samples, the effect of impurities on the mechanical properties of bearing metals, corrosion of nonferrous metals, electrodeposition, the effect on hardness of the cold rolling of metals, aluminum casting alloys, the fatigue resisting properties of duralumin, investigation of alloys for dental use,

the work of the Bureau on pure zinc in connection with the physical constants of metals, new refractories, molding sand research, tests on the tensile properties of nonferrous alloys at elevatetd temperature, mercury vapor poisoning in research work, and possible applications of metal spraying.

Apparatus for the Study of the Corrodibility of Metals

In the study of this property of metals, two general methods are available. The metal may be subjected to a combination of conditions which simulate the actual service to which it is to be subjected, or the metal may be subjected singly to the various influences, which combined, constitute the service environment. There is now available at the Bureau apparatus for a series of different tests as follows: (a) simple immersion within a corrosive medium, the temperature of which is accurately controlled; (b) repeated immersion in a corrosive medium followed by withdrawal into the atmosphere; (c) a modification of (b) which permits holding the specimen in the air for a period as long as one hour if desired which will allow thorough drying of the surface before it is reimmersed; and (d) exposure to a fine mist of the corrosive medium. Apparatus now being developed will permit the specimen to be subjected to a series of conditions successively, the whole cycle being comparable to the actual atmospheric conditions which the material has to withstand.

Resolving Power of Optical Instruments

The Bureau has designed an improved apparatus for determining the resolving power of optical instruments, including the eye, under varying degrees of illumination intensity and contrast. It is hoped that this apparatus will be useful in determining the effects of striae in optical glass on the definition of the instrument in which such glass may be used, and also in determining the harmful results of known quantities of various aberrations present in optical systems.

Effect of the Character of Steel Upon the Results Obtained in Carburizing

Samples of various "normal" and "abnormal" steels submitted to the Bureau by different manufacturers have been carburized and examined microscopically. The structural characteristics of these carburized steels confirm the contention that there is a difference in the "carburizing properties" of steels which show but little difference in their composition as ordinarily determined. These differences consist in variations in the average depth of penetration, as well as in the character of the pearlite. The real significance of the differences, so far as commercial practice is concerned, is still a matter of surmise. The work is being continued, and special attention will be given to the "carburizing behavior" of a set of irons containing unusual impurities such as oxides, nitrogen, etc., in appreciable amounts.

New Glycerin-Water Quenching Medium

In connection with the Bureau's investigation of steels for the manufacture of precision gages, an effort has been made to find a quenching medium intermediate between oil and water. Quenching curves were taken of specimens cooled in water solutions of glycerin. Such solutions fill the gap effectively, so far as the cooling rates at high temperatures are concerned. On the other hand, glycerin and its water solution cool distinctly faster in the lower temperature ranges than quenching oil. This appears to be a desirable property. As a commercial quenching medium glycerin or its water solutions should not be unduly expensive, for although the first cost is high, glycerin does not decompose to any great extent on heating, as is the case with oils. The composition of glycerin water solutions may be easily maintained by hydrometer tests. They do not give off irritating fumes and are harmless to the worker, in contrast with concentrated sulphuric acid sometimes used for this purpose.

NOTES FROM THE U. S. BUREAU OF MINES

Molybdenum as an Alloy Element

THAT molybdenum is one of the most powerful and useful alloying elements in steel has been conclusively demonstrated by experiments conducted by Dr. H. W. Gillett, chief alloy chemist, Department of the Interior, at the Ithaca, N. Y., field office of the Bureau of Mines. While the value of molybdenum as a steel alloy is only beginning to be appreciated and its commercial use is still relatively small, the Bureau of Mines considers that it is destined to become widely used as it deserves to be. The United States has abundant supplies of molybdenum which should be available to replace or supplement other metals used as steel alloying elements which at present must be imported.

The early claims for molybdenum as a specific against fatigue failure of steel, which alleged, directly or by inference, that molybdenum steels were vastly superior to other steels for uses to resist vibration, have not been substantiated in the over-enthusiastic form in which they were made. The Bureau of Mines' experiments show that, with one exception, molybdenum steels, and other alloy steels containing nickel, chromium, vanadium, or a combination of these elements, have equal qualities of endurance, and that no one alloy steel stands out above the others on this score.

The exception is in favor of heat-treated molybdenum steels, for the presence of molybdenum makes the steel require a higher temperature in the drawing or tempering process after quenching, and this higher temperature causes fuller release of quenching stresses. The presence of quenching stresses tends to cause poorer performance under repeated vibration. This, however, is not a very great factor,

and has a noticeable effect only in very hard steels, for example, those of spring temper. For ordinary structural uses, no alloy steel is appreciably superior for use against vibration to any other when the steels are used in such sizes that they harden throughout on quenching. Molybdenum and certain combinations of nickel and chromium confer depth-hardening properties on steel, and hence these have advantages for use in parts of large cross section.

Thus it is evident that, as regards endurance, molybdenum steels are the equals of any, and on some scores have slight advantages, but the advantages are slight instead of large. The choice of a composition of an alloy steel will, therefore, seldom depend on its fatigue properties.

The endurance work of the Bureau of Mines has given results which in general fit in very well with the recent work of the Engineering Experiment Station of the University of Illinois, and which indicate that the conclusions of the Illinois investigation may be extended to apply to a large range of alloy steels.

But, besides corroborating and extending the Illinois results, the work of the Bureau has brought out a point which has not been covered completely by other investigators in this country or abroad, although it has been considered to some extent by most workers in this field. This point is the evil effect on endurance of nonmetallic inclusions. Dirty steel gives far less uniform results on endurance tests than cleaner steel, and dirty steel is certainly unreliable and unsafe where repeated vibration must be endured.

These inclusions, or other similar inhomogeneities in the metal, are probably the cause of many failures in service. From the relationship worked out by the Illinois investigators and others, and corroborated by the Bureau of Mines' tests, the endurance properties of any really clean steel may be quite safely predicted. But when the steel is not clean, it may either give the same results as a clean steel, or far poorer results, depending on whether the most severely stressed spot in a piece made from the dirty steel happens to be locally clean or locally dirty.

The problem of the exact effect of different inclusions or inhomogeneities in steel and other alloys, and the larger problem of how to produce clean steel and alloys, are of vital importance, and involve many factors in the preparation of metallic products, ranging from the methods of elimination of impurities from the ores, down through the smelting of the metals and the melting of the alloys. Much scientific data needed for a proper understanding of the problem is lacking.

To obtain further information on the effect of inclusions, comparisons are being made of endurance tests on specimens cut both with and across the direction of rolling, since the latter, or transverse specimens, usually show the bad effect of inclusions and inhomogeneities

most markedly. As soon as the endurance tests on the series of molybdenum, cerium and comparison steels are completed, tests will be made on a series of nickel-silicon steels previously made by the Bureau of Mines for the Navy, on which tests made by the Navy on properties other than endurance are available. The Navy has supplied specimens cut both longitudinally and transversely, and the Bureau has prepared all these specimens for testing. This work should throw some light on the problem of inclusions. But work with inhomogeneities such as inclusions in steel is difficult because of the irregularity of distribution of the inclusions.

In order to study the effect of different kinds of inhomogeneities in different sorts of alloys, work on certain non-ferrous alloys has been begun.

Prior to the fiscal year of 1922-1923 a series of fifty molybdenum, cerium and other alloy steels was prepared for comparative purposes, in co-operation with the Vanadium Corporation of America, and the Welsbach Company, and the necessary tests, other than endurance tests, were made. After these co-operative agreements ended, the Bureau of Mines continued the endurance tests in order to make the work complete.

Endurance tests are time-consuming, and, save for a short period when the machines were out of commission due to a fire which damaged the laboratory of Sibley college, Cornell university, in which the endurance machines used in this work are located, two endurance machines have been run night and day throughout the present year. These machines will continue to run continuously for a few months longer to complete the program.

Cerium offers no promise of usefulness as an alloying element in steel. Its use tends toward the presence of nonmetallic inclusions and toward troubles consequent upon this defect.

Study of Georgia Clays in Ceramics

Co-operative work between the Department of the Interior and the Central of Georgia railway to determine the value for ceramic use of various clay deposits of Georgia has been concluded at the ceramic experiment station of the Bureau of Mines, Columbus, O. The work was divided into five parts; clay washing; laboratory work on the crude and washed clays; manufacture and testing of refractory materials; manufacture of vitrified face bricks; and manufacture of white ware.

Washing tests on some of the most promising clays were made in the special washer developed by the Bureau of Mines. These tests, supplemented by laboratory tests to determine the burning, shrinkage and other properties of the clays, showed that some of the clays were suitable for maintenance of white ware. Others proved to be excellent filler material, and the Southern station of the Bureau of Mines is using these washed clays in plant practice tests in the filler trade.

The clays selected in general are, if properly prepared, suitable for the manufacture of refractories. Therefore, 20 tons of a selected clay were made up into fire clay shapes at a large manufacturing plant in accordance with plant practice. These bricks have been tested in doors and roof of an electric furnace for melting steel, in oil-fired furnaces; for steel-pouring ladles; in boiler settings; in ceramic kilns; and as bungs in furnaces for making malleable iron. They gave exceptional service in practically all tests.

Experiments are in progress to develop face brick from certain of these clays, and present results indicate that a satisfactory product will be obtained. The purpose of this work is to produce a vitreous, buff-face brick, which type of brick cannot be made from materials at present in use in the South. The bricks dry well and when properly made burn to a pleasing buff without checking.

Semicommercial scale tests at two plants show that several of the Georgia clays can be used in floor-tile bodies. In wall-tile bodies a much smaller proportion of clay is desirable to prevent checking. Factory tests on white ware and electrical porcelain are in progress.

Reduction and Carburization in Iron Smelting

Observations made in experimental work on sponge iron and synthetic cast iron, performed by the Department of the Interior at the Seattle station of the Bureau of Mines, led to certain conclusions regarding reduction and carburization that differ in some respects from prevalent belief. These findings are being further studied. As a result of this work it would seem that it may be possible to produce low-carbon iron from the blast furnace. In order to obtain exact data on the combination of carbon with iron, reduction tests are being carried on with molten iron in contact with solid carbon and with gases. In the course of this work, it was found that gases (methane, acetylene, or carbon monoxide) were valueless for introducing carbon into molten iron, but solid carbon dissolved rapidly.

Melting of Sponge Iron

Experimental work on the production of foundry iron from sponge iron in the electric furnace, performed by the Department of the Interior at the Seattle station of the Bureau of Mines, demonstrated that technically, at least, the process is a success, though large-scale tests are necessary to determine its commercial applicability. Such a process would find application in melting iron in regions remote from blast furnaces, or where establishment of blast furnaces would be impracticable. Sponge iron was melted in batch runs and continuous runs, in various types of furnaces, and under both acid and basic conditions.

The type of furnace found best fitted for the continuous melting of sponge iron is a deep pit furnace with a single electrode and a conducting hearth, The main problems solved were: High recovery

of iron, clean separation of the slag, obtaining metal of a high-carbon content, introduction to the metal of silicon and manganese from the slag to eliminate the necessity of using ferroalloys, and, finally, the removal of sulphur. In order to produce the best quality of gray iron, an auxiliary furnace would be necessary to adjust the final composition of the metal.

Synthetic Foundry Iron

The feasibility of producing a good grade of foundry iron from steel scrap in the electric furnace has been demonstrated in experimental work performed by the Department of the Interior at the Northwest experiment station of the Bureau of Mines at Seattle, Wash. This development permits any manufacturing plant to use all its iron scrap on the spot in making castings equal to if not better than those from cupola iron. Improved methods of charging the 300-pound experimental furnace used by the Bureau of Mines gave more rapid carburization, and carbon contents as high as five per cent were reached. Several heats were made in a 1-ton commercial electric furnace of the Heroult type, at Hoquiam, Wash., and in a 1-ton indirect-arc, rocking furnace in a foundry at Detroit, Mich. In every case, these tests were successful in producing sound, strong gray iron from steel scrap and iron turnings.

Abstracts of Technical Articles

Brief Reviews of Publications of Interest to Metallurgists and Steel Treaters

BEHAVIOR OF MANGANESE IN BASIC OPEN-HEARTH FURNACES. By P. Oberhoffer and F. Koerber, in *Stahl und Eisen*, No. 43, page 329 (1923).

This article discusses the subject in detail and gives a number of diagrams.

INVESTIGATION OF THE MANUFACTURE OF MALLEABLE IRON. By P. Oberhoffer and J. Welter, in *Stahl und Eisen*, No. 43, page 105 (1923).

This article gives the results of the investigation of the various influences of composition, annealing temperatures and oxidizing material used on the properties of the malleable iron as well as the nature of the soft skin formed.

MANUFACTURE OF CRUCIBLE COMPOSITE STEEL. By A. W. F. Green, John Illingworth Steel Co., Philadelphia, in *Chemical and Metallurgical Engineering*, No. 29, page 59-61 (1923).

This article states that it is possible to cast crucible steel of different compositions into the same mold, thus producing a variety of composite steels of unique properties. These steels can be made in no other way.

THE IMPROVEMENT OF CAST IRON BY THE ADDITION OF NICKEL. By E. Piwowarsky and K. Ebbefeld, in *Stahl und Eisen*, No. 43, page 967 (1923).

In this article the authors tell how a mechanical betterment of from 25 to 40 per cent was shown in a high carbon cast iron to which nichrome was added. Additions of more than 1 per cent nichrome showed no added improvement. With the increase of silicon in the cast iron the beneficial effect of nichrome is lost.

COVERING RAILS WITH MANGANESE STEELS. By Roux in *Revue de Metallurgie*, No. 20, page 490 (1923).

The above article states that railway switches and diamonds are now covered with manganese steel by arc welding with an electrode of manganese steel and can be refilled when worn down. Adherence is improved by drilling holes at an angle into the rail. A thin layer of martensite is formed at the surface of the two metals.

HEAT TREATING—ITS PRINCIPLES AND APPLICATIONS. By Charles H. Fulton, director of school of mines and

metallurgy, University of Missouri; Hugh M. Henton, consulting metallurgical engineer and assistant professor of metallurgy and mining, State College of Washington, and James H. Knapp, furnace engineer, Tate-Jones & Company, in *Iron Trade Review*, October 18, 1923, page 1099.

The above article which discusses "The Structure of Iron and Steel" is part two of a series of eighteen installments, which when completed, will be a complete treatise on heat treating. The work is the result of the experience of the three competent authors.

X-RAYS IN THE STEEL INDUSTRY. By Dr. Ancel St. John, Union Carbide & Carbon Research Laboratories, Inc., Long Island City, N. Y., in *Iron Age*, September 27, 1923, page 820.

In this article the origin and properties of X-rays are given. The author discusses the hidden defects in steel and the manner in which they may be found. He finally tells of the work that has already been done.

HEAT-TREATED STEEL PARTS IN SERVICE. By George K. Elliott, metallurgical engineer, Lunkenheimer Company, Cincinnati, Ohio, in *Iron Age*, September 27, 1923, page 810.

The author in the above article explains the effect of long-time drawing conditions or further heat treatment under use. He also discusses the stability of a steel when heated at different temperatures.

OXYGEN IN STEEL MAKING. By F. W. Davis in *Iron Age*, No. 112, page 734.

This article gives the results when oxygen is used in the bessemer, open-hearth and basic processes, and the respective advantages.

THE KNOWLEDGE OF THE ALUMINUM-ZINC ALLOYS. By W. Sander and K. L. Meissner in *Journal* of the Institute of Metals, No. 29, page 633.

The above article gives the complete knowledge of the aluminum-zinc alloys, and the authors show how their results differ from those previously obtained.

METALLURGY AND HEAT-TREATMENT OF STEEL STAMPINGS. By Ralph H. Sherry, metallurgist, International Harvester Co., in *Machinery*, October 1923, page 105.

The above is a four-page article illustrated with microphotographs showing the difference between low carbon steel and other steels. The author points out the causes and effects of grain growth and the annealing temperature at which this occurs; maximum elimination of grain growth is also considered. The fuel advisable for annealing furnaces is finally discussed.

GEAR TOOTH GRINDING. By Franklin D. Jones in *Machinery*, October, 1923, page 85.

The above article gives the various methods and machines used

in this process. The preparation of gears is also discussed. This is a ten-page contribution and is well illustrated.

DURALUMIN. By R. W. Daniels, sales engineer, Bausch Machine Tool Company, Springfield, Mass., in *Journal* of the Society of Automotive Engineers, November 1923, page 427.

This paper deals with the developments and advantages of this new metal and gives its consistency.

ACCURATE MANUFACTURE OF AUTOMOBILE GEARS. By A. B. Bassoff in *Machinery,* November 1923, page 209.

The author describes in detail this process of manufacture as well as the machines used.

EXAMINES MASS EFFECT ON IRON. By O. Smalley in *Iron Trade Review,* December 27, 1923, page 1724.

The above article is an abstract of a paper presented at the International Foundrymen's congress, held in Paris, September 12 to 15. Tests were made to determine the chemical and physical phenomena occurring in cast iron as affected by the rate of cooling. The governing factors appear to be the pouring temperature and the rate of filling the mold.

METALLURGY AND HEAT-TREATMENT OF STEEL STAMPINGS. By Ralph H. Sherry in *Machinery,* October, 1923, page 105.

The above article explains the difference between low carbon steel and other steels. The author points out the causes and effects of grain growth and the annealing temperature at which this occurs. The article deals largely with the question of maximum elimination of grain growth.

HIGH-SPEED STEEL FOR CAST TOOLS. By J. M. Quinn, Chicago in Iron Age, December 27, 1923, page 1711.

The author gives a detailed description of the process of making high-speed steel for cast tools. It is a four-page article and is illustrated with photomicrographs of the steel in the different conditions.

SCIENTIFIC INVESTIGATION IN THE STEEL INDUSTRY. By P. Goerens, in *Stahl und Eisen,* No. 43, page 1191 (1923).

This article states that the iron industry differs from most of the other chemical industries inasmuch as the chemical processes are usually worked out and the reactions known before the process is placed on a commercial basis. A history is given of chemical control in the iron industries and the effect of scientific investigation is pointed out. Definite examples of benefits thus derived are mentioned in the operation of various furnaces, regenerators, processes and methods of heat treatment.

Reviews of Recent Patents

By
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1,457,718. Electric Furnace. Irving R. Valentine, assignor to the General Electric Co., a corporation of New York.

This patent discloses an electric arc furnace with the usual refractory lining, having a refractory heat conducting solid body, as for example a graphite block, which is located at the top of the charge, or floats upon the charge, and arc means for heating said body or block. The furnace is particularly adapted for melting low melting point metals such as aluminum, copper, brass, etc. In the use of the furnace the solid block which covers the charge is heated by the arc and conducts the heat through the block to the charge while at the same time due to the mass of the block its temperature is not excessively high so that it does not cause volatilization of the charge, as would be the case if the arc played directly upon or above the charge.

1,457,772. Forming and Tempering Disk Wheels. George H. Forsyth of Harvey, Ill.

This patent discloses a die for forming disk wheels, comprising a matrix or bed and a platen or stamp. Both the matrix and platen are hollow and water cooled and are provided with grooves on their molding faces through which the water can flow when the die is closed. Water is continually flowed over the grooves in the face of the matrix or lower die.

In the operation of the die the heated blank is positioned between the platen and the matrix and the platen is forced downward to shape the blank. Simultaneously with the complete closing of the die, valves in bottom of the platen open and permit the water in the hollow platen to circulate through the grooves in the face of the platen. Thus when the blank is completely formed, water is circulated in direct contact with both sides of the blank to cool and temper the same while it is held against distortion in the forming die.

1,457,780. Gas-fired Melting Furnace. Henry O. Loebell, New York, N. Y., assignor to Doherty Research Co. of New York, N. Y.

This patent describes a gas-fired melting furnace for brass and other alloys containing easily vaporized constituents.

The furnace is divided into an upper combustion chamber and a lower melting chamber by an arch provided with a number of small open-

ings through which the heat may radiate from the upper to the lower chamber. The walls of the combustion chamber and the dividing arch are heated to incandescence by regenerative gas burners and the heat radiated downward to melt the charge below. The gaseous pressure in the upper combustion chamber is kept higher than the vapor pressure of the metal in the melting chamber to prevent volatilization of any portion of the charge.

1,458,568. Method of Producing Rustless Iron Alloy. Wilson Bennet, Wellington, New Zealand.

This patent pertains to a method of producing rustless iron or stainless steel by developing the same directly from the ores or from scrap iron or steel, and consists in partially refining the molten iron, reducing the metal oxides of chromium ore and refining the resulting metal in an electric furnace by the aid of suitable reducing and refining agents, transferring the molten iron and ferrochromium to a separate combination arc and resistance electric furnace and subjecting the combined charge to a mixing, refining and deoxidizing process at the same time.

1,459,409. Process of Carburizing Hollow Articles. Harry W. McQuaid, Canton, O., assignor to the Timken Roller Bearing Co. of Canton, O., a corporation of Ohio.

This invention relates to a process of preventing carburization on the interior or exterior of hollow bodies, and dispenses with the practice of coating the portion of the article which is not to be carburized with a carburization shielding material, by clamping the hollow articles together in airtight relation so as to form a tube and then if only the exterior of the hollow articles are to be carburized, sealing the ends of the tube, or if the interior of the articles are to be carburized the exterior of the tube of hollow articles is surrounded with a shielding tube and the interior is of the tube of hollow articles packed with the carburizing material.

1,459,570. Forgeable Steel as an Article of Manufacture. Linus P. Burrows, Erie, Pa., Lena B. Archer, Executrix of said L. P. Burrows, deceased.

This patent describes a forgeable steel which is formed by adding a purplish powder produced from nickel ore to a charge of metal scrap in the proportions of a half to 10 per cent of the powder, and claims to produce a forgeable steel capable after being heated to 2200 degrees Fahr. and water tempered, of being used as a cutting tool and without further treatment of being forged. The process of forming the purplish powder from nickel ore is disclosed in patents 1,424,710 and 1,424,711 to the same inventor.

1,459,910. Method of Removing Rust from Metal Articles. Julian S. Gravely, Wytheville, Va., assignor to Winchester Repeating Arms Co. of New Haven, Conn.

This patent describes a method of removing rust from metal articles by immersing or subjecting the articles to the action of the ammonium salt of an organic acid, for example, a 10 per cent solution of ammonium citrate in water. The articles are preferably immersed in the solution and left there a greater or less time depending upon the thickness of the rust coating; when removed and washed the articles are free from rust and are not attacked by the solution no matter how long they remain therein.

1,460,048. Electrical Heating Element. Percy A. E. Armstrong, Loudonville, and Ralph P. DeVries, Newtonville, N. Y. Said DeVries assignor to said Armstrong.

This invention relates to a metallic electric resistance material which may be mechanically worked, as by hot or cold rolling, etc., or may be cast. A preferred composition of the alloy is given as an alloy steel containing 0.05 to 1 per cent carbon, more than 10 per cent and less than 30 per cent chromium, 2 to 6 per cent silicon, 0.20 to 10 per cent tungsten and the principal part of the remainder, iron. In lieu of tungsten any other high melting point metal of the sixth group of the periodic table except chromium may be used.

1,460,049. Workable Metal Article. William B. Ballantine, London, England.

This patent describes a process for forming rustless or stainless steel articles which differs from the customary method, in that instead of forming a stainless steel alloy ingot and working it into shape, the inventor takes a core of ordinary steel and casts upon this core a covering of any desired stainless steel alloy at a temperature sufficient to cause the core and coating to weld. The stainless steel coated ingot is then worked down in the usual manner.

1,460,106. Electric-Furnace Melting of Manganese Scrap. Wesley G. Nichols, Chicago, Ill., assignor to American Manganese Steel Co. of Chicago.

This patent describes the prior methods of melting manganese steel scrap in an arc furnace by bringing the charge cautiously and very gradually to the melting point so as to prevent oxidation of the manganese constituent. It then points out that temperature alone does not consume the manganese ingredient but that the oxidation is a surface reaction and the protracted time of the prior melting processes, exposes a large amount of surface during the boiling of the metal so that the manganese loss is relatively high. The improvement consists in charging the scrap into the furnace and then supplying current to the furnace at an initially high wattage to thereby quickly bring the bath to a molten state before oxidation of the manganese can take place.

1,460,395. Pickling Bath and Process for Pickling Iron and Steel. Otto Vogel, of Dusseldorf-Oberkassel, Germany.

This patent states that when iron and steel articles are pickled in acids capable of dissolving the iron oxide and other undesirable substances from the surface of the article, the iron becomes brittle, and the inventor proposes to prevent this brittleness by adding to the pickling acid an aromatic compound in which several carbon atoms of the ring nucelus are united with nitrogen atoms, as for example chinoline. Several examples of suitable aromatic compounds are given, such as chinoline, chinoline derivatives, acridine, etc. In preparing the pickling bath 1 per cent of the chinoline compound is added to the pickling acid.

1,460,790. Welding Rod. James H. Critchett, of Niagara Falls, Reynolds, of Scottdale, Pa.

This patent describes a welding compound or flux useful in restoring burnt tool steel to its original state and for welding steel or cast iron. A preferred composition of the compound is oxide of iron 5 per cent, black manganese dioxide 25 per cent, and borax 70 per cent.

1,460,790. Welding Rod. James H. Critchett, of Niagarra Falls, N. Y., assignor to Union Carbide and Carbon Research Laboratories, Inc., a corporation of New York.

This patent relates to a metal to be used in welding, filling, sheathing and the like, where it is desired that the added metal shall have great hardness. The patent states that the use of high-carbon steel as a welding metal of great hardness is unsatisfactory because the increased carbon content permits overheating to take place at lower temperatures and promotes the formation of blowholes. These disadvantages are overcome and a much greater hardness is obtained by the use of a suitable quantity of chromium in the welding metal. The carbon content of the welding metal is preferably reduced when chromium is used. A preferred composition contains carbon 0.5 per cent and chromium 1.1 per cent.

1,460,830. Metallurgical Process. Herman G. C. Thofehrn, of Roselle Park, N. J.; Donald H. McLean, administrator of said Herman G. C. Thofehrn, deceased.

This patent discloses a new alloy for use in scavenging steel, copper, etc. The specification states that the use of aluminum alone as a steel scavenger is unsatisfactory because of the aluminum oxide which is dissolved in the molten metal and states that the use of magnesium alone gives too rapid a reaction to permit uniform treatment throughout the mass. These objections may be overcome according to the inventor by using an alloy of aluminum and magnesium, which may vary from

five to fifty per cent magnesium, according to the metal to be treated, and the speed of reaction desired. The alloy is formed by first melting the aluminum and then adding the proper proportion of magnesium. The metals going into the alloy should be of the highest purity obtainable.

1,460,855. Annealing Box. Irvin F. Lehman, of Pittsburgh, assignor to Blair-Knox Co. of Pittsburgh, a corporation of New Jersey.

This patent relates to annealing boxes which are made up from sheet metal plates united by welding. The object of the invention is to provide a box with a smooth exterior so that no projections or shoulders are left to be attacked by impinging flames. This is done by forming the body of the box of one sheet of metal which is bent into a rectangular form, with rounded corners, and the ends overlapped and welded. The overlapping ends are brought to a welding heat by the use of a water-gas flame and the parts are hammered until a homogeneous weld is made and the excess metal at the joint thoroughly distributed so that in the finished article the joint is of substantially the same thickness as the balance of the box. The top or cover portion is shaped from a single piece of metal and welded to the body of the box in a similar manner, so as to provide a box of substantially uniform wall thickness.

1,461,178. Alloy. Hugh S. Cooper, of Cleveland, assignor by mesne assignments to Kemet Laboratories Co., Inc., a corporation of New York.

The object of this invention is to mix nickel, silicon and aluminum in suitable proportions to produce an alloy of relatively low cost, which has a high degree of toughness, is noncorrodible, has a low melting point, and is extremely hard at a red heat. The alloy is composed of a preponderating amount of nickel or cobalt, with from 3 to 12 per cent of aluminum and 3 to 8 per cent of silicon. Molybdenum or tungsten may be added if desired. The alloy is produced by weighing out the specified amounts of metallic silicon, aluminum and nickel in the form of shot and placing the aluminum and silicon in the bottom of the crucible under the nickel. The furnace need not be brought to the melting point of the nickel, as the combination of the aluminum and nickel takes place below that point.

1,461,444. Magnesia Refractory. Wallace W. Greenwood of Worcester, Mass., assignor to Norton Co. of Worcester, Mass., a corporation of Massachusetts.

This patent proposes to reduce the tendency of magnesia refractories to crack when heated to high temperatures by pre-shrinking the magnesia and bonding it with certain specified materials. In preparing the mixture, ordinary calcined magnesia is fused or sintered in an electric furnace, and the magnesia grains are then bonded with plaster-of-

paris, and clay in the proportions of prefused magnesia 82 per cent by weight, plaster-of-paris 3 per cent by weight, and ball clay 15 per cent by weight.

1,461,643. Alloy. Frederick M. Becket, of Niagara Falls, N. Y., assignor to Electro Metallurgical Co. of Niagara Falls, N. Y., a corporation of West Virginia.

This patent describes a new alloy for use in purifying iron and steel or for forming alloy steels. The claims cover a wide range of tertiary alloys of magnesium, silicon and manganese in which the silicon is used in excess of equimolecular proportions to magnesium and the manganese is present in lesser molecular proportions than silicon. Iron may be present in varying proportions, but is not an essential ingredient. One example of the alloy given by way of illustration, contains magnesium 10.20 per cent, manganese 52.30 per cent, silicon 32.10 per cent, iron 4.50 per cent, carbon 0.30 per cent.

1,462,460. Heat Treatment of Light Castings. Stanley Apgar, High Bridge, N. J., assignor to Taylor-Wharton Iron & Steel Co. of High Bridge, N. J.

This patent states that the decarburization and oxidation of the skin of manganese steel chain and other light castings can be prevented by charging the castings in a cold state into a furnace heated to at least 800 degrees Cent. and then heating to the usual temperature for the heat treatment of manganese steel and quenching. This treatment can be completed in about 30 minutes per charge and it not only improves the wearing properties of the articles treated but also increases their strength.

1,462,899. Furnace for Melting and Casting. George H. Benjamin, New York, N. Y., assignor to Anatmos Metals and Furnace Corp. of New York.

This patent describes a furnace for melting and casting metals on a large scale in a substantial vacuum so that the gases developed in the melting will not be reabsorbed in the metal. The furnace comprises a long tunnel or kiln which is substantially air tight. One end of the kiln is devoted to melting and the other to casting, and the furnaces are moved from one end to the other and poured by means controlled from the outside of the kiln. The inventor prefers to use tilting electric furnace for the melting and casting.

1,464,312. Electrical Resistance Element. Frank A. Fahrenwold, Cleveland, O.

This patent describes an alloy having a high coefficient of electrical resistance, and highly resistant to corrosion either by the high temperature or chemical effects of the electric current. The preferred composition of the alloy is iron 78.9 per cent; chromium 18 per cent; titanium 2.5 per cent; manganese 0.5 per cent, and carbon 0.10 per cent. Zirconium may be substituted for titanium if desired.

News of the Chapters

SCHEDULED REGULAR MEETING NIGHTS

FOR the convenience of visiting members, those chapters having regular meeting nights are listed below. It is desired that all secretaries whose chapters are not included in the list communicate with the National office in order that the list may be as complete as possible.

Boston—Third Thursday.

Cleveland—Fourth Friday, Cleveland Engineering Society rooms, Hotel Winton; meeting at 8 p. m.

Chicago—Second Thursday.

Hartford—Tuesday nearest 10th of month.

New Haven—Third Friday.

New York—Third Wednesday, assembly room, Merchants Association of New York, ninth floor, Woolworth building.

Philadelphia—Last Friday, Engineers' club.

Tri City—Third Thursday.

BOSTON CHAPTER

THE December meeting of the Boston chapter of the American Society for Steel Treating was held on Thursday, Dec. 13. This meeting was opened at 3:30 p.m. and took place at the plant of Gray & Davis, Inc., Cambridge, Mass. The members and guests, numbering about 85, were taken through the entire plant, which was in full operation, thus affording an opportunity to see the many types of machines of particular interest to those individuals interested in die and press work. After the inspection the guests were given a very excellent supper.

C. H. Alvord, factory manager of the plant, expressed his interest in the work of the society. G. C. Howard, maintenance engineer, gave a very interesting article on "Cyaniding of Steel." Mr. Howard gave a detailed report of the method of cyaniding used at this plant, types of salt baths tried, kinds of pots used and the results obtained. S. C. Spalding, Halcomb Steel Company, Syracuse, N. Y., addressed the members and guests by an illustrated lecture on "The Comparison of the Rate of Penetration on Various Steels in Carburizing." Mr. Spalding gave a short outline of the different methods of carburizing and a description of the means used in carrying out their test, illustrated in detail with slides and curves. This paper was very well received by the members.

Announcement was made that the next meeting, scheduled for Jan. 17 will be held at the Massachusetts Institute of Technology.

BUFFALO CHAPTER

The Buffalo chapter of the American Society for Steel Treating held their first meeting of the season on Dec. 14 at the Hotel Buffalo. The program for this evening consisted in the presenting of three papers on tool steel. The first paper entitled "The Application of Tool Steels in the Manufacture of All-Steel Cars," was given by F. J. Lazure, local engineer, American Car & Foundry Co., Buffalo. The second paper by Hans Buerk, Buerk Tool Works, Buffalo, was entitled, "The Relation between Tool Hardening and Tool Design and Manufacture." "Reminiscences in the Manufacture of Crucible Tool Steel," was the title of the third paper and was presented by J. E. Sandmeyer, Atlas Steel Corporation, Dunkirk, N. Y. The chapter has planned an excellent program for the year, and announce that each meeting will be devoted to one general subject. They plan to have three or four 15 to 20-minute talks at each meeting, thus covering the practical application of the topic, the fundamental bases and the manufacture of the materials discussed. In this way, the chapter expects to increase its membership.

CHICAGO CHAPTER

The Chicago chapter of the American Society for Steel Treating held their December meeting on Thursday, the thirteenth, at the City club, 315 Plymouth court. W. R. Chapin, director of testing department, E. C. Atkins Company, Indianapolis, Ind., presented a practical illustrated paper entitled. "Some Observations in the Hardening of Steel." Mr. Chapin has had many years experience and consequently gave a very capable presentation.

CINCINNATI CHAPTER

The Cincinnati chapter of the American Society for Steel Treating held their regular monthly meeting on Dec. 13 at the Ohio Mechanics institute, Canal and Walnut streets. The paper of the evening was presented by T. Y. Olsen, vice president, Tinius Olsen Testing Machine Company, Philadelphia, and was entitled, "Testing Equipment Developed for the Use of Metallurgists and Steel Treaters." Mr. Olsen who is well known, has been directly connected with the design and manufacture of testing and balancing machines and their equipment. A lively discussion following his presentation.

CLEVELAND CHAPTER

The Cleveland chapter of the American Society for Steel Treating held a meeting on Friday, Dec. 28 at 8:00 p.m. in the Cleveland Engineering Society rooms, Hotel Winton. "Specifications and Inspection of Raw Materials" was the title of the general subject upon which

discussion of various subdivisions was given in the form of short talks by various members of the chapter. "Steel for Automatic Machine Work" was discussed by D. M. Gurney, Warner & Swasey Company; "Carburizing Steels" by C. F. Beeler, Cleveland Metal Treating and Welding Company; "Strip Stock for Tubing" by M. L. Burchfield, Rotor Pneumatic Company; "Structural Steels" by Harry Smith, Bourne-Fuller Company; "Forging Steels" by R. Rolf, Columbia Axle Company; "Spring Steel" by C. G. Shontz, Perfection Spring Company; and "Tool Steel" by A. S. Townsend, Cleveland Twist Drill Company.

Dinner was served at Hamilton's restaurant, at 7:00 p.m. preceding the meeting.

Printed announcement has been made of the course to be given in the practical heat treatment of steel, under the auspices of the Cleveland chapter of the American Society for Steel Treating, at Case School of Applied Science, Department of Metallurgy, under the direction of Prof. H. M. Boylston. This course is for the purpose of giving elementary instruction in the principles of practical heat treatment. It consists of a series of twenty evening lectures, one hour in length and two hours of laboratory demonstrations each evening in addition. The following subjects will be covered: Principles of Heat Treatment; Equipment; Forgings; Case Hardening; Applied Heat Treatment; Metallography, and Physical Tests. These lectures will be given by Professor Boylston, members of the faculty of Case school and by certain members of the American Society for Steel Treating who are specialists in the subjects they will cover.

A small fee for the course including the laboratory demonstrations will be charged. Information regarding this course may be obtained from Prof. H. M. Boylston, Department of Metallurgy, Case School of Applied Science, Cleveland, or any of the officers of the Cleveland chapter of the A. S. S. T. Enrollments accompanied by tuition fee will be accepted by Professor Boylston at any time before the first meeting, which is to be held on Friday, January 18.

This course is open to all interested in Cleveland and vicinity and especially to the members of the American Society for Steel Treating.

DETROIT CHAPTER

On Nov. 26, the Detroit chapter of the American Society for Steel Treating held a meeting at Palestine Lodge house at 8:00 p.m., preceded by dinner at 6:30 p.m. Prof. H. E. Moore, University of Illinois, Urbana, Illinois presented a very interesting illustrated lecture entitled, "Fatigue of Metals." Professor Moore is an authority on this subject and his address was very well received. An interesting discussion followed the presentation.

The chapter held a meeting on Dec. 17 at 8:00 p.m. in the General Motors building. This meeting was in the form of a round table dis-

cussion of heat treating troubles. The following members led in the discussions: C. N. Dawe, Studebaker Corporaton; H. Martin, Dodge Bros.; H. Northrup, Hudson Motor Car Corporation; and Glenn Coley, Timken Detroit Axle Company.

Dinner was served at 6:30 on the fourteenth floor of the General Motors building.

HARTFORD CHAPTER

The Hartford chapter of the American Society for Steel Treating held a meeting on December 11. This meeting was addressed by Prof. W. Trinks, Carnegie Institute of Technology on the subject of "Automatic Control of Furnace Temperatures and Atmosphere." Prof. Trinks described the various types of control devices now on the market for the purpose of automatic temperature control when using gas or oil, explaining that that has been an achievement made necessary by the more widespread use of electric furnaces with automatic control devices, permitting the easy maintenance of constant temperatures. This lecture was illustrated and aroused considerable interesting discussion. Two national officers, W. H. Eisenman and W. S. Bidle were also present at this meeting, which was very well attended. Dinner was served preceding the meeting.

INDIANAPOLIS CHAPTER

The Indianapolis chapter of the American Society for Steel Treating held their November meeting at the Hoosier Athletic club. L. C. Dunn, Montgomery Chemical company, Detroit, gave an address entitled, "Carburizing Methods and Uses." This meeting was well attended and was considered the best meeting the chapter has had.

LEHIGH VALLEY CHAPTER

The fall meeting of the Lehigh Valley chapter of the American Society for Steel Treating was held on December 7 at Easton public library, Easton, Pa., at 8:00 p. m. This meeting was addressed by Dr. Richard Moldenke on the subject: "Metallurgical and Other Observations Made During a Recent European Journey."

Dr. R. Moldenke is one of the most prominent foundrymen in the world. He has been a moving spirit in the American Foundrymen's association and is a member of all the leading technical societies. Among other works from his pen are "Principles of Iron Founding" and "Practice of Iron Founding." These books are the standard authoritative works on iron foundry practices.

He has traveled extensively and has recently returned from a trip through England, France, Germany, and Italy.

After a previous trip to Germany he spoke before the Engineers' club of the Lehigh Valley and our chapter on January 19, 1922, and his reminiscences of personal contacts with the leaders in Germany made this one of our most interesting meetings.

MILWAUKEE CHAPTER

On Friday, December 14, the Milwaukee chapter of the American Society for Steel Treating held a meeting at Hotel Blatz. E. W. Ehn, metallurgist, Timken Roller Bearing company, Canton, O., spoke to the members on the subject of "Carburizing." Mr. Ehn, who has had a number of years of experience on this subject, gave a very capable presentation, after which an interesting and instructive discussion ensued. Dinner was served at 6:30 p. m., previous to the meeting.

NEW HAVEN CHAPTER

The New Haven chapter of the American Society for Steel Treating held their November meeting on the sixteenth of the month at 8:00 p. m. in the assembly room of the New Haven Gas Light company. The speaker for this meeting was H. M. Candee, mechanical expert, Bristol company, Waterbury, Conn., who spoke on "Automatic Control as Applied to Modern Heat Treating Departments."

The chapter held a meeting on December 21 at the same meeting place. Joseph A. Doyle, vice president, W. S. Rockwell company, New York City, presented a very interesting article on "Selection of Tools for Industrial Heating Operations." Mr. Doyle discussed the principles governing the selection of heat treating equipment. The subject was also considered from the standpoint of the shop and not merely from the standpoint of the office where selection of equipment is frequently made without regard to fundamental essentials that would be better appreciated from the shop point of view. The meeting was very well attended.

NEW YORK CHAPTER

The New York chapter of the American Society for Steel Treating held their regular monthly meeting on Wednesday, December 19 at 8.00 p. m. in the assembly rooms of the Merchants' Association of New York, ninth floor of Woolworth building. This meeting was addressed by Stanley P. Rockwell, consulting metallurgist, Hartford, Conn., on "Measurement of Carbon Penetration in Carburized Steels," which was illustrated by lantern slides. Dinner was served at 6:30 p. m. at the Post-Keller restaurant.

The chapter has announced that their next regular meeting will be a joint meeting with the New Jersey Chemical society and will be held on Monday, January 14 at the Stetter restaurant, Newark, N. J.

NORTH WEST CHAPTER

The regular monthly meeting of the North West chapter of the American Society for Steel Treating was held on December 15 at 8:00 p. m. at the Manufacturers' club, 100 Builders Exchange. E. W. Ehn, metallurgist, Timken Roller Bearing company, Canton, O., addressed this meeting, choosing for his subject "Case Hardening," which included the selection of materials, proper processes, and the influence of certain improper treating of steel on the final result. Mr. Ehn, who has had extensive and varied experience on this subject, which is of keen interest, gave a very capable presentation. The meeting was well attended.

PHILADELPHIA CHAPTER

The Philadelphia chapter of the American Society for Steel Treating held a meeting on Friday evening, November 30 at 8:00 p. m. at the Engineers' club. "The Heat Treatment of Cast Iron" was the subject chosen by the speaker, Bradley Stoughton, professor of metallurgy, Lehigh university, who is the author of "The Metallurgy of Iron and Steel." By the courtesy of the Clark Equipment company, Buchanan, Mich., a motion picture was shown on the following subject, "The Electric Furnace in the Steel Foundry." This was a vivid and forceful presentation of electric foundry practice showing the use of Heroult electric steel furnaces in the production of cast steel disk motor truck wheels used in Packard, Kelly-Springfield, Fifth Avenue Coach, Nash, etc. Dinner was served at 6:45 p. m. in the club dining room.

PITTSBURGH CHAPTER

The Pittsburgh chapter of the American Society for Steel Treating held a meeting on Tuesday, December 4 at 8:00 p. m. in the Hawaiian room, William Penn hotel. The speaker for this meeting was C. P. Richter, Central Steel company, Massillon, O., who gave a very interesting illustrated address entitled, "The Manufacture of Forging Steels." A lively discussion followed the presentation. Supper was served at 6:30 in the cafeteria of the William Penn hotel.

RHODE ISLAND CHAPTER

On Wednesday, December 19 at 8:00 p. m., the Rhode Island chapter of the American Society for Steel Treating held a meeting at 92 Weybosset street. The speaker for this evening was H. O. Loebell, combustion engineer, Combustion Utilities corporation, New

York City, who addressed the members on the subject of "Development and Possibilities of the Application of Gas in Industrial Furnaces." Mr. Loebell is a recognized authority in the combustion field, having organized one of the first concerns devoted to the manufacture of efficient industrial gas appliances. He took an active part in the designing and developing of a gas-fired brass melting furnace.

Under the auspices of the Providence Gas company a demonstration and exhibition was given of fifteen furnaces in actual operation, together with all makes of automatic controls.

This meeting was considered the best that the chapter has had.

SCHENECTADY CHAPTER

The Schenectady chapter of the American Society for Steel Treating held a meeting on Tuesday, November 20 at Union college. Prof. Enrique Touceda, who was guest of honor and speaker of the evening, is professor of metallurgy, Rensselaer Polytechnic institute and consulting engineer, American Malleable Castings association. Professor Touceda gave a technical talk on the "Malleable Iron Process" which was well diversified and covered points of general metallurgical interest. A lively discussion followed the very capable presentation.

SOUTH BEND CHAPTER

The South Bend chapter of the American Society for Steel Treating held a meeting on Wednesday, December 19 at the South Bend Y.M.C.A. The program for this evening consisted of two papers being presented, one by E. J. Lowry, Hickman-Williams company, entitled, "The Relation of the Blast Furnace to the Steel Industry" and the other by V. A. Crosby, Studebaker corporation, on "Foundry Practice." This meeting was very well attended and proved of great interest to those connected with iron and steel.

SPRINGFIELD CHAPTER

The Springfield chapter of the American Society for Steel Treating held a meeting on Tuesday, December 18 at 8:00 p. m. in the Chamber of Commerce rooms, Myrick building. This was a general get-together meeting with an informal round table discussion lead by some of the members of the chapter.

ST. LOUIS CHAPTER

On November 17, the St. Louis chapter of the American Society for Steel Treating held a meeting at the American Annex hotel. A detailed report of the Pittsburgh convention was given by Messrs.

Clark, Pendergast, Swander and Buck, delegates of the chapter. A round table discussion followed. Dinner was served at 7:00 p. m. preceding the meeting.

The chapter held their December meeting on Monday, the seventeenth of the month at 8:00 p. m. at the same meeting place. The program for the evening consisted of the presentation (through the courtesy of the Bethlehem Steel company) of a 5-reel motion picture and general talk on "The Manufacture of Steel and Steel Products, Including the Mining of Ore." There was also a short illustrated talk given on "Mayari Pig Iron." A get-together dinner was served at 6:45 p. m.

SYRACUSE CHAPTER

The Syracuse chapter of the American Society for Steel Treating held a meeting on December 7 at the Onondaga hotel. R. A. Cole, engineer, Norton company, Worcester, Mass., addressed the members at this meeting, choosing for his subject, "The Grinding of Steel," which was illustrated with stereopticon slides. This meeting was of special concern to those interested in the subject of abrasives.

TORONTO CHAPTER

The Toronto chapter of the American Society for Steel Treating held a meeting on Friday, November 30 at 8:15 p. m. in the Day building. E. F. Collins, consulting engineer, industrial heating department, General Electric company, Schenectady, N. Y., addressed this meeting on the subject "Past, Present and Future of the Metallic Resistor Furnace." This lecture was followed by the presentation of lantern slides showing the various applications of this type of furnace. Mr. Collins is an outstanding authority on the above subject and his presentation was given in a very capable manner.

TRI CITY CHAPTER

The regular monthly meeting of the Tri City chapter of the American Society for Steel Treating was held on November 15 at the Davenport chamber of commerce at 8:00 p. m. H. Bornstein, secretary of the chapter gave a short talk on the Pittsburgh convention. He announced that it was the decision of the national officers to hold the spring sectional meeting in the Tri Cities on May 22 and 23, 1924. The speaker of the evening, T. Y. Olsen, spoke to the members on the use of testing machines, illustrating his lecture with lantern slides.

His presentation was very interesting and brought forth much discussion. A. H. Putnam lead in a round table discussion which covered the subject of "The Heat Treatment of Cast Iron." Dinner was served at 7:00 p. m. preceding the meeting.

The chapter held their December meeting on the twelfth of the month at the same meeting place. E. W. Ehn, metallurgist, Timken Roller Bearing company, Canton, O., addressed the members on the subject of "Carburizing." Mr. Ehn is an authority on this subject having prepared several papers for the British Iron and Steel institute. His presentation brought forth much valuable discussion. The students of the Tri City chapter's night course on steel and its treatment were invited to attend this meeting. C. H. Burgston, member of the executive committee of the chapter gave a brief report of the progress which has been made in the course thus far. Dinner was served at 7:00 p. m.. This meeting was very well attended.

WASHINGTON CHAPTER

The Washington chapter of the American Society for Steel Treating held a meeting on Friday, December 14 at 8:00 p. m. in the auditorium of the New Interior Department building. E. Gathmann, Gathmann Engineering company, Baltimore, Md., gave an illustarted address on the subject of "Ingot Molds." The speaker discussed the various types of ingot molds which are manufactured, and touched on many of the phases of good ingot making practice. A lively discussion followed which terminated late in the evening and only at the request of the chairman.

WORCESTER CHAPTER

The Worcester chapter of the American Society for Steel Treating held their regular monthly meeting on Tuesday evening, December 18 at the Metal Trades rooms, 44 Front street. John H. Nelson, research engineer, Wyman and Gordon company, presented a paper on "Response of Certain Steels to Heat Treatment with a discussion of Flow Lines in Forging." Data was presented showing the results of heat treatment on different steels used in automobile forging. It was shown that chemical analysis alone does not indicate with certainty the response to heat treatment, but that test specimens from each heat must be taken to determine the proper drawing temperature. Flaws in the ingot and their effects on bars were shown. Several slides showed the grain and flow lines in a properly forged crankshaft and in a poorly forged one.

It was announced that the next regular meeting of the chapter will be held on Thursday, January 17, 1924, at which time A. H. Kingsbury, Crucible Steel company, Harrison, N. J., will speak on "Tool Room Troubles."

ADDRESSES OF NEW MEMBERS OF THE AMERICAN SOCIETY FOR STEEL TREATING

EXPLANATION OF ABBREVIATIONS. M represents Member; A represents Associate Member; S represents Sustaining Member; J represents Junior Member, and Sb represents Subscribing Member. The figure following the letter shows the month in which the membership became effective.

NEW MEMBERS

AIELLI, J. A. (M-12), tool maker, Worthington Pump & Machinery Co., Cambridge, Mass., *mail* 4 Henchman Street, Boston.

AIKEN, F. W. (M-11), secretary-treasurer, International Burr Corporation, Watertown, N. Y.

ALLISON, F. H., JR. (M-11), research metallurgist, Westinghouse Electric & Mfg. Co., East Pittsburgh, *mail* 232 Meyran Avenue, Pittsburgh.

ANDERSON, H. V. (M-12), assistant secretary and purchasing agent, V. D. Anderson Co., Cleveland.

BAIRD, JOHN (M-11), E. W. Gillett, Ltd., Toronto, Ontario, Canada.

BATES, D. W. (M-12), assistant superintendent, Vilco Machine Co., Benton Harbor, Mich., *mail* 410 Court Street, St. Joseph, Mich.

BLAKE, F. W. (A-12), salesman, Steel Supply Co., Chicago, *mail* 125 North Jefferson Street.

BOOTH, H. C. (S-10), sales representative, Columbia Steel & Shafting Co., Hartford, Conn.

BROMM, WM. F. (M-11), junior member of Fred Bromm Co., Chicago.

BUCKLEY, C. W. (M-1), engineering department, Wilson-Maeulen Co., New York City, *mail* 306 North High Street, Mount Vernon, N. Y.

BURGESS, F. E. (M-11), Burgess Norton Mfg. Co., Geneva, Ill.

CAMPBELL, R. D. (M-12), assistant works manager, Union Electric Steel Corporation, Carnegie, Pa.

CAVEN, FRED (M-12), heat treater, Canada Illinois Tool Co., Ltd., Toronto, Ontario, Canada, *mail* 187 Duffries Street.

CHASE, MORRIS (M-11), A. Finkl & Sons, Chicago.

COLLINS, C. R. (M-12), rate setting department, Worthington Pump & Machinery Co., Cambridge, Mass., *mail* Y.M.C.A.

COVER, GERALD M. (Jr-11), student, Case School of Applied Science, Cleveland, *mail* 2073 Adelbert Road.

DEUCHLER, L. Y. (M-11), assistant metallurgist, American Autoparts Co., Detroit.

DITTMAR, C. (M-12), sub-foreman, heat treating inspection department, North East Electric Co., Rochester, N. Y., *mail* 140 Argo Park.

EARLS, J. B. (A-12), salesman, Colonial Steel Co., New York City, *mail* 501 Norton Street, Rochester, N. Y.

FENGLER, A. (M-11), tool room foreman, R. Wallace & Sons Manufacturing Co., Wallingford, Conn.

FISHEL, W. P. (M-12), assistant professor of chemistry, Vanderbilt University, Nashville, Tenn.

FLANSBERG, RAY (Jr-11), 1428 West Monroe Street, Chicago.

FORD, T. J. (M-12), heat treating department, Bethlehem Steel Co., Lehigh Mills, Bethlehem, Pa., *mail* 847 East 4th Street.

FRISBIE, F. G. (M-1), chemist, Duquesne Steel Foundry Co., Coraopolis, Pa.

GRAY, O. L. (M-11), assistant to chief inspector, Cutler Hammer Mfg. Co., Milwaukee, Wis., *mail* 699 28th Street.

HANDYSIDE, GEO. (M-11), 27 Georgetown Street, Buffalo, N. Y.

HEGEMAN, J. S. (S-9), representative, Bethlehem Steel Co., Detroit.

HEIL, OTTO (M-11), Aluminum Company of America, Cleveland.

HOLLENBECK, E. H. (M-12), inspection department, Bethlehem Steel Co., Bethlehem, Pa., *mail* 111 East Church Street.

HOYLER, ERNEST (M-12), engineer of tests, American Locomotive Co., Dunkirk, N. Y., *mail* 717 Grant Avenue.

HOYT, C. E. (M-12), secretary-treasurer, American Foundrymen's Association, 140 South Dearborn Street, Chicago.

KALIDOVA, J. J. (M-12), shop engineer, Chicago Screw Co., Chicago, *mail* 1026 South Homan Avenue.

KAMPE, H. R. (M-11), heat treater, Chicago Pneumatic Tool Co., Detroit.

KIRCHEN, G. (Jr-11), tester, A. O. Smith Corporaton, Milwaukee, Wis., *mail* 1083 27th Street.

KIRKHAM, WM. J. (M-11), heat treater, Witherow Steel Co., Pittsburgh, *mail* 708 Chess Street, Coraopolis, Pa.

KLINGER, R. (M-11), 2456 West 40th Street, Cleveland.

KNIGHT, R. B. (M-12), North East Electric Co., Rochester, N. Y.

KOLOSY, A. (M-12), Bethlehem Steel Co., Bethlehem, Pa., *mail* 911 Cayuga Street, Pembroke, Bethlehem, Pa.

KUSZLER, WM. D. (M-12), master mechanic, Minneapolis Electric Steel Castings Co., Minneapolis, Minn., *mail* 2904 Buchanan Street, N. E.

LARECY, T. A. (A-11), salesman, Firth-Sterling Steel Co., Cleveland.

LAROSH, R. (M-12), foreman heat treating department, International Motor Co., Allentown, Pa., *mail* 1324 Main Street, Northampton, Pa.

LAZAER, J. W. (A-1), district sales manager, Chicago Flexible Shaft Company, New York City.

LEARY, C. F. (M-11), 85 Pleasant Street, Dorchester, Mass.

LEINROTH, J. P. (A-11), sales department, Public Service Gas Co., Newark, N. J.

LONG, H. J. (M-12), exp. department, Brown-Lipe-Chapin Co., Syracuse, N. Y., *mail* 116 Lynwood Ave., Eastwood Station.

LUKEY, J. B. (M-11), D. O. James Mfg. Co., 1120 West Monroe Street, Chicago.

MACDONALD, A. F., JR. (M-12), general foreman heat treating department, Bethlehem Steel Co., Bethlehem, Pa., *mail* 433 Montclair Avenue.

MAVES, H. A. (M-12), instructor in forge shop of Arsenal Technical Schools, Indianapolis, Indiana, *mail* 2612 East Michigan Avenue.

MUSSELMAN, R. W. (M-12), assistant general foreman heat treating department, Bethlehem Steel Co., Bethlehem, Pa., *mail* 749 North Sixth Street, Allentown, Pa.

MYNOTT, E. P. (M-12), assistant superintendent of inspection, North East Electric Co., Rochester, N. Y.

ORSBERG, A. (M-11), chemist, G. E. Wills Pharmacy, Rockford, Ill., *mail* 1827 6th Street.

OSTERLOH, R. M. (M-11), manager, Milwaukee Tool and Forge Co., S. Milwaukee, Wis.

PHILLIPS, C. A. (M-11), treating department, Cotta Gear Co., Rockford, Ill., *mail* 1224 North Court Street.

RICHARD, J. A. (M-11), foreman heat treating department, Chicago Pneumatic Tool Co., Detroit.

ROBERTS, H. J. (A-12), salesman, Chas. Engelhard, Inc., Detroit.

ROSTEK, C. A. (M-12), treating department, Pittsburgh Knife & Forge Co., Pittsburgh, *mail* 367 Woodruff Street.

SCHLACHTER, H. (M-11), 4128 North Maplewood Avenue, Chicago.

SCOFIELD, W. C. (M-12), foreman blacksmith, Illinois Central R. R. Co., Chicago.

SHIELDS, C. W. (M-12), metallurgical department, Bethlehem Steel Co., Bethlehem, Pa., *mail* 447 Vine Street.

SIEG, W. W. (M-12), heat treating department, Ingersoll Rand Co., Phillipsburg, N. J., *mail* 54 North Third Street, Easton, Pa.

SMALL, H. (M-11), 3234 North 17th Street, Philadelphia.

STEPHENS, H. D. (M-12), raw material inspection and analysis department, New Departure Mfg. Co., Bristol, Conn., *mail* 113 School Street.

STUART, A. H. (M-12), chemical engineer, Ford Motor Co., Detroit, *mail* 611 Ellis Street, Ypsilanti, Mich.

TALLMAN, J. R. (M-12), laboratory assistant, Ingersoll Rand Co. Phillipsburg, N. J., *mail* 35 Bullman Street.

TAYLOR, S. S. (M-12), metallurgical department, Dodge Bros., Detroit, *mail* 4687 Vancouver Avenue.

TEDESCO, R. P. (M-12), chemist, Standard Tool Co., Cleveland, *mail* 8609 Kenmore Avenue.

TENNANT, J. (M-11), heat treater foreman, Minnesota Steel Co., Duluth, Minn., *mail* 6 B Fourth Street, Morgan Park.

TOOHEY, H. W. (M-11), foreman machine shop, American Schaeffer & Budenberg Corporation, Boston, *mail* 4 Hubbard Street, Jamaica Plains, Mass.

VAN BERGEN, S. (M-12), Tuthill Spring Co., Chicago, *mail* Y. M. C. A.

VON SCHLUTTER, C. H. (A-9), salesman, Firth-Sterling Steel Co., New York City, *mail* 102 Sherman Place, Jersey City, N. J.

VOORHEES, S. B. (M-11), metallurgist and chief chemist, International Harvester Co., Auburn, N. Y.

WEBB, W. W. (M-11), Dover Stamping & Mfg. Co., Cambridge, Mass. *mail* 385 Putnam Street.

Items of Interest

A VERY remarkable work in industrial co-operation is being carried on by the Engineering Extension Service of Purdue University, by Prof. John F. Keller, a prominent member of the A. S. S. T., and engineering extension specialist in iron and steel connected with the university. He has established courses throughout the various towns in Indiana. The course usually runs for one semester, or about six months, with classes meeting once a week.

During the present term, Professor Keller has industrial classes in Fort Wayne on Monday, Wabash on Tuesday, Marion on Wednesday, Anderson on Thursday, and Indianapolis on Friday.

Beginning with the new year, a new group of cities will be organized, consisting of Kokomo, Muncie, Richmond, New Castle and Connersville.

This engineering extension service being inaugurated by Professor Keller is a pioneer piece of work, and one that is attracting wide attention by all educational institutions having engineering courses. Professor Keller's present enviable reputation is being constantly increased and augmented by the wonderful success he is having in his present work.

Announcement is made that the Calorizing Company, Pittsburgh, has acquired exclusive sales rights for Hybnickel, the heat-enduring alloy perfected by Mr. Victor Hybinette. The arrangements which make this announcement possible provide a single source for all that has been developed by the Calorizing Company and Mr. Hybinette working independently. In addition, the production facilities of both organizations will be preserved.

As a direct result of this union of interests, it becomes possible immediately to quote lower prices on heat-enduring castings, to offer service through the Calorizing Company's representatives throughout the country and to insure a prompt supply of large or intricate castings.

Hybnickel will now be known as Calite. The original analysis Calite will continue to be supplied to those who have become accustomed to it and for whose requirements it is best adapted.

Mr. Hybinette will be associated in a consulting capacity with the Calorizing Company.

The company offers data outlining many uses for Calite castings and showing the usefulness of the alloy under the continuous influence of temperatures up to 2100 degrees Fahr.

A portable electric recording instrument has been developed by the Westinghouse Electric & Mfg. Co., It is known as type R and includes an electric self-winding clock for giving records at speeds up to 24 in. per hour. For slower speeds, up to 4 in. per hour, a hand wound clock can be used.

EMPLOYMENT SERVICE BUREAU

The employment service bureau is for all members of the Society. If you wish a position, your want ad will be printed at a charge of 50c each insertion in two issues of the Transactions.

This service is also for employers, whether you are members of the Society or not. If you will notify this department of the position you have open, your ad will be published at 50c per insertion in two issues of the Transactions Fee must accompany copy.

Important Notice

In addressing answers to advertisements on these pages, a stamped envelope containing your letter should be sent to AMERICAN SOCIETY FOR STEEL TREATING, 4600 Prospect Ave., Cleveland, O. It will be forwarded to the proper destination. It is necessary that letters should contain stamps for forwarding.

POSITIONS WANTED

METALLURGIST—EXECUTIVE. Twenty years experience as chemist, metallographist and executive in iron and steel foundry. Also heat treating and annealing castings and forgings, electric converter and open-hearth, rolled material (billets, skelp and tinplate). Connection desired where experience will be valuable and opportunity to demonstrate ability. References furnished if desired. Address 11-5.

TOOL HARDENER. Experienced tool hardener wishes position with reliable firm. Can give best of references. Any locality will be considered. Address 11-10.

SALES ENGINEER, Metallurgical engineer, superintendent, assistant superintendent or any position requiring a man with a technical training. Technical graduate. Married. Age 35 years. Connected with reliable firm for a number of years in the capacity of metallurgical engineer in conjunction with mill operation and sales. Address 11-20.

COMBUSTION ENGINEER Specialty heat treatment furnaces. Has after his graduation 13 years experience in study and development of industrial furnaces. Constructed 200 experimental furnaces of his own design for gas, oil, powdered coal and anthracite clum. For years connected with leading concerns in furnace specialty. Owns patents, publications, has good references. Wishes full or part time employment with some big concern. Undertakes investigation, reporting and consultation work in fuel economy or furnace efficiency line. Write O. Lellep, 111 West Seventy-Sixth Street, New York City.

TOOL HARDENER has had 12 years experience with carbon, high speed and alloy steels, covering all phases of heat treating. Wishes position with firm where individual can show ability. American. Married. Age 35. Can give first class references. Eastern location preferred, but will go anywhere. Address 12-10.

METALLURGICAL WORK—Young man with college training desires position with firm that will give opportunity to specialize in metallurgical work and will give with it valuable experience in this line. Has had several years experience in chemical and metallurgical research and laboratory work with government departments. Plant experience in power plant and maintenance departments and general experience in engineering work. At present employed as metallurgical engineer in Pittsburgh district. Will furnish complete details of training, experience and reasons for making change. Address 1-10.

HEAT TREATER wishes position. Has had five and one-half years experience with two large automobile companies. Address 1-5.

POSITIONS WANTED

METALLURGIST AND CHEMIST, 12 years practical experience in heat treating all grades of steel; chemical and physical testing and pyrometry. Capable executive open for connection in technical or executive capacity. Member S. A. E. and A. S. S. T. Address 1-20.

POSITIONS OPEN

SALESMAN WANTED to handle a line of industrial furnaces, hardening room equipment, metallurgical, chemical and high temperature engineering equipment and service, by a well established and reputable engineering company. Chicago territory. Address SERVICE, 708 West Madison Street, Chicago.

SALESMAN—Single young man with one to two years' selling experience, to call on industrial trade. Fundamental electrical knowledge, and some mechanical and metallurgical knowledge needed. Engineering schooling preferred but not essential. A live energetic young man, willing to travel and willing to put in some extra effort at improving and preparing himself for advancement. Long established mechanical and electrical equipment of specialty nature and leading quality. Moderate salary and expenses to start and short training period. Some service on equipment required and rendered by salesman. State selling experience fully, age, schooling, general experience and references of selling ability and general character and salary. Address 11-30.

ASSISTANT SUPERINTENDENT OF FORGE LABORATORY in large university in middle west. Salary $2200.00. Candidate should be technical graduate with practical experience in the heat treatment of steel. Excellent opportunity for young man who wishes to enter the teaching profession and assist in the development of a course of instruction in heat treatment and in the conduct of research work. Address 11-25.

RESEARCH METALLURGIST AND METALLOGRAPHIST wanted by a large corporation. Sound fundamental training essential, few years additional practical experience in research or operations desirable but not necessary. Salary according to qualifications. Address 8-10.

FOR SALE

For sale in Chicago—One Stewart Gas Furnace, 20 x 12 x 48. One Barkling Furnace, 30 x 15 x 60. In first-class condition. Address 1-15.

The McGraw-Hill Book Co., Inc., New York City, has recently published *The Metallurgy of Iron and Steel,* by Bradley Stoughton, head of the department of metallurgy, Lehigh university. It is bound in cloth and contains 519 pages 6 x 9 inches. This is the third edition that has been published on this subject, and is a thorough revision of the first and second editions. The extensive changes and developments in iron and steel metallurgy that have occurred in the past eight years are outlined, thus showing the commercial and industrial progress that has recently been made. The following subjects are covered: Iron and Carbon; Manufacture and Purification of Pig Iron; Manufacture of Wrought Iron and Crucible Steel; the Bessemer Process and the Open-Hearth or Siemens-Martin Process; the Electro-Metallurgy of Iron and Steel; the Ingot-Making Stage of Manufacture; the Mechanical Treatment of Steel; Iron and Steel Founding; the Solution Theory of Iron and Steel; the Constitution of Steel and Cast Iron; Malleable Cast Iron; Heat Treatment of Steel; Alloy Steels; Corrosion of Iron and Steel; and the Metallography of Iron and Steel.

This book is profusely illustrated with charts, diagrams and photographs.

The Chemical Resistance of Engineering Materials by Marston L. Hamlin and Francis M. Turner Jr., has recently been published by the Chemical Catalog Co., Inc., New York City. It contains 267 pages and is cloth-bound.

During the war when engineers who had had no previous chemical experience were called upon to build chemical plants, they were greatly handicapped inasmuch as they did not have the information available that was so necessary, and it was the situation of the chemical industry during this period that has occasioned the writing of this book. Its object is first, to give the results of experiment and general knowledge fully and as accurately as possible; second, to serve as a bibliography of the subject by referring to all the sources used; and third, to arouse further research and publication along this line by showing those parts of the field which are not completely covered, and by suggesting ways of making results more practically useful.

The following subjects are covered in the nine chapters: Sulfuric Acid and Other Acids and Metals; Bases and Alkaline Salts; Neutral Substances; Selection of Material for Specific Equipment; and Concrete in Chemical Equipment Construction.

Standardization of industrial production has been one of the important factors in enabling Germany to maintain its industrial machine intact, in the face of the multitude of obstacles now confronting that country, states a bulletin of the American Engineering Standards committee recently issued.

"The extent to which Germany has so far succeeded in keeping her industrial machine intact, is due in no small part to the elaborate scale on which her standardization work is performed," it is stated in the bulletin, which was prepared by Dr. P. G. Agnew, secretary of the American Engineering Standards committee, who recently returned from Europe, where for two months he made a study of the standardization movement and the manner in which European developments in this direction are likely to affect American industry.

"The elaborateness of the organization for the work, its activity, and

S. M. Co. Brinell Machine

This machine applies a pressure of 3,000 Kilos to a 10 mm. ball and gives results in Brinell numerals, the international standard for indicating hardness of metals.

The Pressure is applied quickly and evenly, and a patented feature prevents the leakage of the hydraulic fluid.

Pieces from $\frac{3}{16}$ inch to 12 inches may be accommodated. The anvil is adjustable to irregular shaped pieces.

The Standard Machine Adopted by

American Can Co.
American Machine & Mfg. Co.
E. C. Atkins & Co.
Canadian Fairbanks Morse Co.
Carbon Steel Co.
Carnegie Steel Co.
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Curtis Aeroplane & Motor Co.
Dayton Engineering Laboratories
Dominion Steel & Foundry Co., Ltd.
Eagle Pitcher Lead Co.
Firth-Sterling Steel Co.
Henry Ford & Son, Inc.
General Electric Co.
Hughes Tool Co.
Latrobe Electric Steel Co.
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Maxwell Motor Co.
McMyler Interstate Co.
Nash Motors Co.
Oliver Chilled Plow Works
Parish & Pool Co.
Piston Ring Co.
Pittsburgh Model Engine Co.
Pittsburgh Testing Laboratory
Pollack Steel Co.
Railway Steel Spring Co.
Standard Foundry Co.
Standard Steel Car Co.
Standard Steel Spring Co.
Studebaker Corp.
Underwriters' Laboratories
Union Switch & Signal Co.
Vanadium Alloys Steel Co.
Westinghouse Electric & Mfg. Co.

And Many Others.

Send for descriptive bulletin 103

SCIENTIFIC MATERIALS COMPANY
"Everything for the Laboratory"
PITTSBURGH, PA.

the scale on which it is being carried out constitute a new development in industrial organization.

"Practically every important manufacturing concern in Germany is officially participating in the industrial standardization program of that country. More than a thousand German companies have formal standardization organizations within their own works. These organizations are called 'standards bureaus.' The larger firms have branch bureaus in the separate departments, or in the separate factories. One of the well known companies has 21 such branch bureaus, employing in all a special staff of more than 100. Another firm has a permanent full-time staff of over 200 in its various branch bureaus. In all of the great firms the bureau reports directly to the general manager."

The extent to which industrial life in Germany has been co-ordinated, it is stated, is shown by the fact that more than 700 German national standards have been adopted. This includes only those in which several different industries are concerned, and which are approved by the central national body. These include fundamental engineering standards as: standard diameters, tapers, sizes of keys, threads, fits, etc.; materials; tools; measuring instruments and gages; machine parts, including handles, ball and journal bearings, etc.; gears; and sizes of paper.

In addition to this work of the central body, and closely correlated with it are no less than 65 special industry committees actively working on such subjects as: the standardization of pipe fittings, piping, and accessories; welding; steel construction; concrete and reinforced concrete; fire fighting equipment; windows, doors and stairways; foundry practice; the printing trades; merchant marine; locomotives; motor trucks; laboratory apparatus; photographic supplies; nonferrous metals; precision tools; sand, gravel and street paving material; typewriters; highway bridges; rolling mills; and railway car construction.

A striking example is cited of the efficiency of national standardization as it has been developed in Germany, in the case of a rush order placed with German manufacturers for 200 locomotives for delivery to Russia. Production of different parts was allotted to 17 different manufacturers to be produced strictly upon the plan of interchangeable parts, no one manufacturer making a complete locomotive. No serious practical difficulty was encountered in filling the order. The inspectors made a particularly striking test of the feasibility and accuracy of the plan by ordering a complete locomotive to be assembled from parts chosen at random from the parts furnished by the 17 manufacturers. It proved to be ready for service immediately after assembly without the necessity of any disassembling for readjustment.

Standardization engineering is now a recognized profession in Germany. The rapid development of standardization organizations within the companies has made a large demand for such work. Advertisements for standardization engineers and for such positions regularly appear in the engineering press.

An interesting development of the last few years is the appearance of consulting engineering firms specializing in standardization work. There are now five such firms in Germany. This work is closely connected with industrial or efficiency engineering, in which there is now great and growing interest in Germany. In general, it appears to be much more closely connected with the movement for industrial standardization than is the case in this country. The largest of these firms devotes about half of its time to standardization work, employing a staff of over forty. They have as their

Pouring Electric Furnace Steel From One of 6-Ton Ladles

A Valuable Service to Steel Buyers

It is our policy and practice to co-operate with our customers and prospects to such an extent that we can supply that particular grade or analysis of tool steel or alloy steel best suited to that particular purpose for which the steel is to be used. We are prepared to furnish not only the ordinary classes of high-grade steels made to our customers specifications, but also to co-operate with them in the manufacture of new and special alloy steels.

We would like to make a thorough study of your requirements, so that with special care that is exercised in the selection of raw materials and the constant attention that is given to workmanship, we can feel that we are supplying our customers with steel which will give the greatest service and efficiency in the products they produce. Our Metallurgical Department is at your service. You can call on our men to go to your factory or your men are welcome to come to the SIMONDS STEEL MILLS with samples of your products to discuss this matter. Our chemical, physical and metallurgical laboratories are most modern and complete.

Our research men are not only thoroughly trained in the theoretical science of high-grade steel making, but also experienced in the practice of the same.

Simonds Saw and Steel Co.

Steel Mills — Lockport, N. Y.

Edgar T. Ward Sons Co., *Distributors*

BARS — SHEETS — BILLETS

clients trade associations as well as individual firms, the latter including both large and small companies.

One of their clients is the trade association representing the motor vehicle industry In this work they perform many of the services that would be done by an ordinary headquarters standardization staff.

Of the companies which are their clients, some maintain their own standards bureaus, which take care of the greater part of the detailed work, leaving to the consulting firm only the more important and difficult questions. In other cases, the consulting firm does a large amount of the detailed work.

Another most interesting development is the work of consulting engineers on trade catalogs for companies. This is particularly significant, as it is carrying standardization a step farther than is usual, by introducing it into the sales organization and sales policy. In this, careful consideration is given to the question of limiting the number of types, ranges and sizes offered for sale, placing proper emphasis in the catalog on these particular items on which the company wishes to concentrate, and, in general, in featuring and often advertising the relation of the firm's products to the standardization movement.

Charles M. Campbell formerly with the Pioneer Alloys Products Company has accepted a position as superintendent of the Monroe Steel Castings Company, Monroe, Mich. Mr. Campbell took up his new duties Nov. 1.

F. J. Ryan & Company have opened a branch office at 540 Flatbush avenue, Hartford, Conn. This office will be under the direction of Edwin L. Willson, who has had a number of years of experience in metallurgical work, specializing on heating and melting problems, and who has been identified with the New England industry for some time.

Alvan T. Simonds, president of the Simonds Saw and Steel Company of Fitchburg, Mass., is offering $1500 in awards to pupils of high schools, trade schools and normal schools in the United States and Canada, who will write essays on "Sharing Our National Income." Full information may be obtained by writing directly to Mr. Simonds.

Firth-Sterling Steel Company, McKeesport, Pa., have recently published a sixty-page book entitled, "Firth-Sterling S-Less Stainless Steel." This gives the history of stainless steel as well as its applications and possibilities.

Nelson Littell, formerly second assistant examiner in the metallurgical division of the United States Patent Office has opened an office for the practice of patent and trade-mark law in the Bowery Savings Bank building, 110 East 42nd street, New York City. For the past four years, Mr. Littell has had charge of the examination of applications for patents relating to metal founding, including gray iron, steel, malleable castings, etc., and expects to specialize in metallurgical and chemical patents. Mr. Littell is a member of the A. S. S. T.

Hybinette gives Calorizing exclusive rights to Hybnickel

Thousands of tons of metal annually are reduced to scrap by necessary exposure to high temperature. Moreover, many chemical processes have been barred from commercial development by lack of adequate heat-enduring castings.

This problem has been solved in recent years by Victor Hybinette and the Calorizing Company, working independently through Hybnickel and Calite.

Now a combination of these two independent factors has been achieved. So industry has available at a single source the highest development in heat-enduring alloys at a price that makes their use possible even on a tonnage basis.

Hybnickel, hereafter to be known as Calite, will now be available for use with the combined co-operation of our own engineering staff, supplemented by Mr. Hybinette. We are happy to announce that he will be associated with us as a consultant.

Added advantage will be found also in service through our representatives throughout the country and increased production facilities especially adapted to the making of large or intricate castings.

Write for full information and new low prices.

THE CALORIZING CO.

311 Oliver Building, Pittsburgh, Pa.

Eastern Office: 50 Church St., New York

District Offices:

224 S. Michigan Ave., Chicago
General Motors Building, Detroit
West Building, Houston
Leader News Building, Cleveland
Commerce Building, Kansas City

Former analysis Calite Castings will still be made for the trade accustomed to them and for whose requirements the original alloy is particularly adapted There is no one heat-enduring alloy that meets every need. We recommend and offer for each use the alloy best suited to the purpose

The new analysis Calite opens a wider field for heat-enduring castings. It is making a commercial success of processes hitherto confined to the laboratory by the high cost or inadequacy of heat resisting alloys. Its low cost makes tonnage production practicable. Increased facilities make large castings available.

J. E. Stead, died at Redcar, Yorkshire, England, on Oct. 31. Mr. Stead was a brother of the noted journalist, W. T. Stead, and was the acknowledged British authority on the manufacture and metallurgy of steel, and famous as a metallurgical chemist. He was the recipient of numerous scientific degrees and for a time president of the Iron and Steel institute. Mr. Stead was born in 1851.

Arthur D. Little, president of Arthur D. Little, Inc., Cambridge, Mass., was elected life member of the corporation of the Massachusetts Institute of Technology at the fall meeting of the corporation, held on Oct. 24.

Louis R. Kruger has resigned as general superintendent and mechanical engineer of the Cruver-Peters Co., Chicago, Ill., and has accepted a position as mechanical engineer and adviser to Chas. Stein of California. His new address is 805 Bush street, San Francisco, Calif.

Frank Garratt, for the past eight years connected with the industrial interests of Latrobe, Pa., has resigned as general superintendent of the Latrobe Electric Steel Co. Mr. Garratt was for several years general manager of the Hudson Reduction Co., manufacturer of metallic and ferrotungsten, and is experienced in the manufacture of high-speed steel and ferrotungsten. Prior to his connection at Latrobe, he was metallurgical chemist for the Firth-Sterling Steel Co., McKeesport, Pa., and was well known in the Pittsburgh district as a tool steel chemist.

Samuel T. Harleman has resigned as assistant to vice president and general sales manager of the Atlas Steel corporation, Dunkirk, N. Y., and will be connected with Henry Disston & Sons, Inc., Tacony, Philadelphia, as assistant manager of the steel sales department. Mr. Harleman graduated from Lehigh university in 1901 in mechanical engineering and after five years in the motive power department of the Lehigh Valley railroad, entered the steel business with the Bethlehem Steel Co. at the Bethlehem plant, leaving in 1918 to go with the Atlas company.

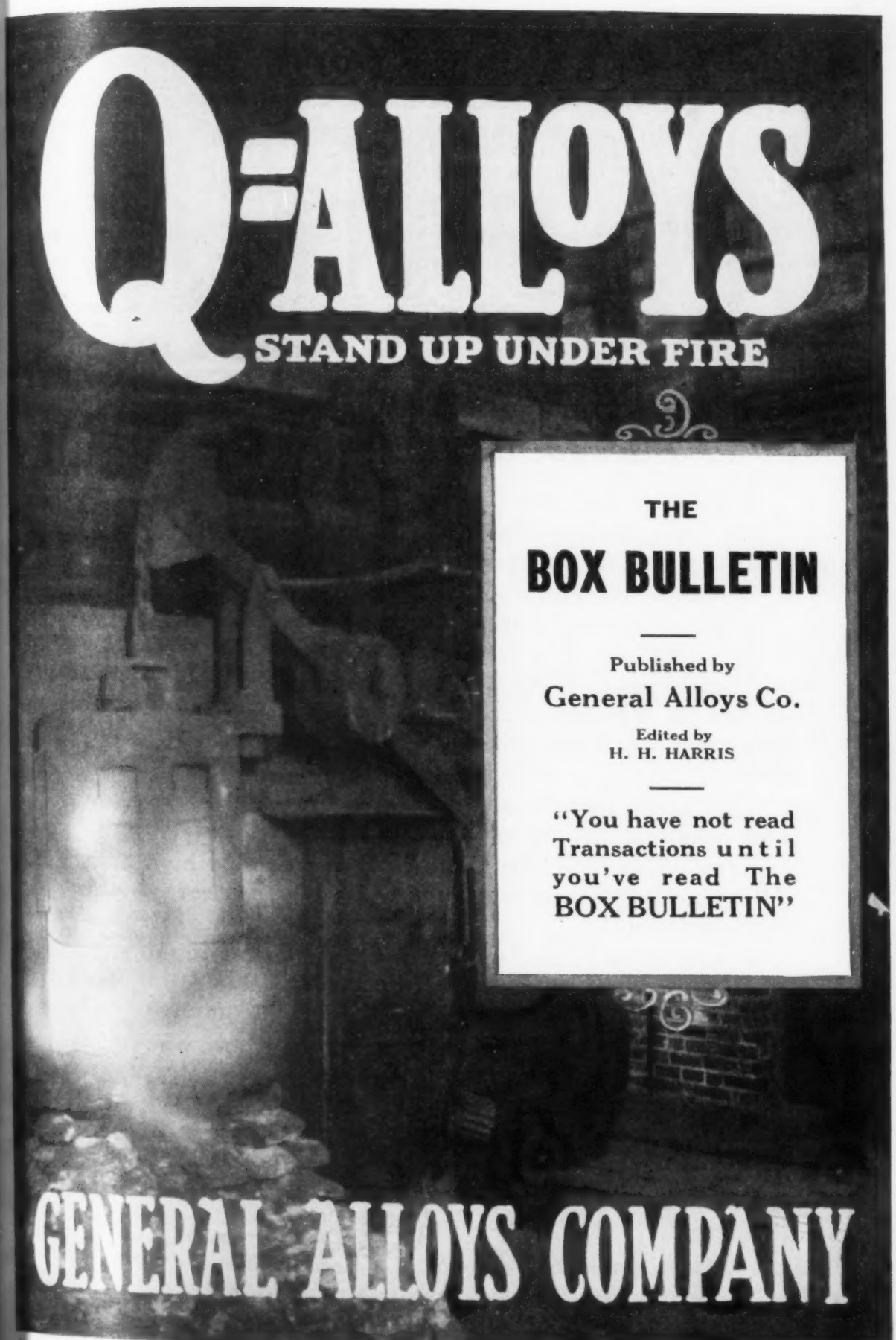
Clinton G. Armstrong, formerly consulting metallurgist for Chicago Flexible Shaft Co., and research metallurgist for Western Electric Co., has joined the Calorizing Co., Pittsburgh, and will serve as sales engineer in its Chicago office.

AMERICAN GAS FURNACE CO. Carburizing Machines	—For better, faster and more uniform carburizing at lower costs.
WILSON-MAEULEN CO. Pyrometers	—For more accurate temperature measurements.
Rockwell Hardness Testers	—For controlling raw material temper and finished product hardness.
CUTLER STEEL CO. Duraloy	—For longer life of cyanide and hardening pots and boxes.
RODMAN CHEMICAL CO. Carbo and Bull Dog	—For more uniform and reliable case hardening.
Quenching Oil	—For faster quenching without distortion or crackage.

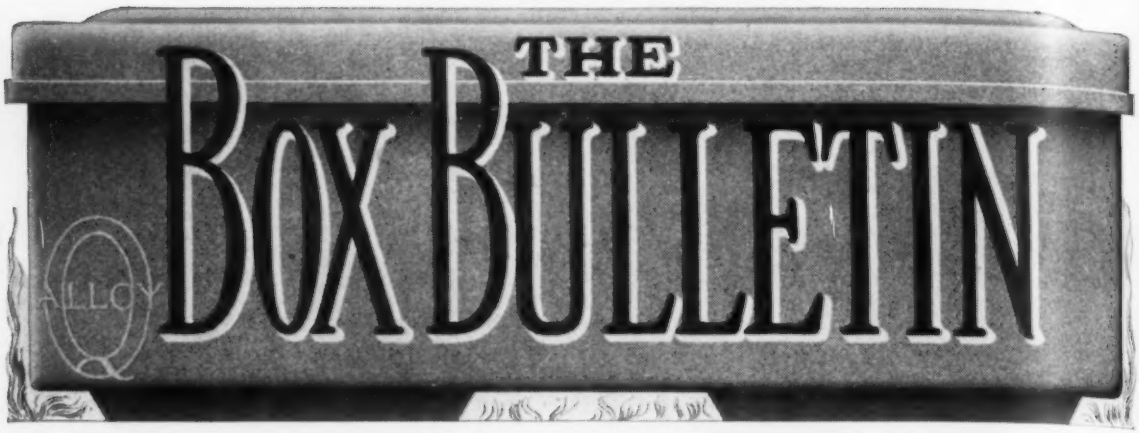
New England Heat-Treating Service Co., Inc.

Hartford, Conn.

Send for our free data sheets.


Q=ALLOYS
STAND UP UNDER FIRE
THE
BOX BULLETIN
Published by
General Alloys Co.
Edited by
H. H. HARRIS
"You have not read Transactions until you've read The BOX BULLETIN"
GENERAL ALLOYS COMPANY

BOX BULLETIN SUPPLEMENT



To You: Our Friends, We Owe Our Success of the Past Year

You sit in judgment. Our future is in your hands.

By our product—by the service we render—by our sincerity and integrity you will judge us.

Q-Alloys are entering their sixth year, their sales in October, November, and December were the largest since their inception.

The buyers of Q-Alloys have bought maximum quality to obtain maximum economy. They have made large expenditures, hundreds of thousands, to obtain Q-Alloy Quality.

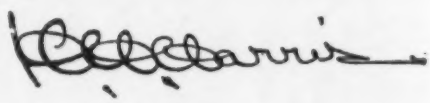
They could have spent thousands less, for lesser quality, and obtained trifling economy, or suffered loss.

They could have spent more for established high price Alloys and obtained inferior quality and inferior service. Hundreds did.

If you are in accord with the practice of buying quality to obtain economy—then is it not sound logic to buy the highest quality to obtain the maximum economy?

Those who agree with this contention—those who have bought Q-Alloys have built this business.

We respectfully solicit their continued patronage on the basis of their experience with Q-Alloys, and their satisfactory business relations with this Company.



BOX BULLETIN SUPPLEMENT

Our Policy

Is it RIGHT, or WRONG?

Read this and think it over, you may have faced the same problem.

It cost money to maintain the Q-Alloy Policy in 1919. It cost money to maintain it in 1920, 1921, and 1922. It cost more money to maintain it in 1923. The question, vital to us, is "Will the policy of 'QUALITY FIRST' make money for us in the end?" Is Quality First a successful policy for any concern?

We have lost considerable "Profit," by not manufacturing a Cheaper Alloy in response to a "Popular" demand. We are well fitted, by experience, facilities, finances, low overhead, etc., to manufacture Cheaper Alloys. We can successfully compete in price and quality with any and all of the "Cheaper" alloys on the market by manufacturing such alloys ourselves. We've got the "Vim and Vigor" to sell them too.

Possibly you've wondered why we don't. We've given the matter considerable thought, and we've decided, for the present at least, not to manufacture a "Cheaper," low priced alloy.

First let us define a Cheaper Alloy. By "Cheaper Alloy" we mean a Heat Resisting Alloy selling at a substantially lower price than Q-Alloys. To sell at a substantially lower price, such an alloy would have to be made at a lower cost. That's logical, isn't it? To make an alloy at a substantially lower cost we could readily do any of the following:

1. Decrease our Nickel and Chromium content.
2. Buy Cheaper Nickel and Chromium.
3. Employ "Green Sand" Moulds instead of Baked Moulds.
4. Employ ordinary iron Moulders.
5. Eliminate sand-blasting and surface area checking of every casting.
6. Ship overweight castings.
7. Use cheaper means of Melting.
8. UTILIZE SCRAP.
9. Eliminate close technical supervision.
10. Adopt a "Replacement" policy instead of "Cash Rebate."

By utilizing scrap alone we could reduce cost 10c lb., or more. By Moulding in Green Sand we could make a very substantial reduction.

Any of the above described "economies" would have a direct effect on the Quality of the product.

BOX BULLETIN SUPPLEMENT

The only argument that competitors advance against Q-Alloys is "They're too good. It isn't necessary to hold to such close chemical and physical specifications. It isn't necessary to mould in Baked Moulds, slight porosity doesn't make much difference." "Using oxidized scrap does not affect quality." "You don't have to spend so much to get quality." Maybe these competitors, and the people who buy their stuff, are right. If so—we're wrong, and that's what we want to find out.

We don't think Q-Alloys are "Too Good." We know that they are not good enough. We believe that the best raw materials we can buy are none too good—that the best workmen we can hire are subject to "Human Error" PLUS—that we who direct this concern have lots, and lots to learn every day in every way.

Therefore, knowing that the best product we can make has fault enough, could we knowingly, conscientiously, and consistently relax our vigilance, use poorer grades of raw materials, or cut our QUALITY, and DESERVE success.

We do not believe we would deserve success if we did not use our maximum facilities and intelligence in the manufacture of Q-Alloys, and we do not believe we would be successful were we to cheapen our product in response to the "Popular" demand for a "Cheaper" Alloy.

Maybe we're wrong, and the users who have believed in us and placed their business with us are wrong too. Perhaps some of the conservative buyers of Q-Alloys exercised poor judgment. Maybe Cadillac, for instance, should not have standardized on Q-Alloys, and bought some cheaper alloy instead. Maybe Dodge Bros. and Buick made a mistake, and Reo did too.

Maybe Not—?

Maybe "Cheap" Alloys are the coming thing, and American buyers won't pay the price for Q-Alloy Quality. Maybe the 11 manufacturers of cheap alloys (5 dead, 3 dying, 3 going strong) are right. Maybe the buyers who bought and are buying their products are better off by far than if they spent their hard earned cash for Q-Alloys,—and;

Maybe Not—?

Time will tell. In the meantime we contend that a fair price paid for highest quality of material and labor in any manufactured article from a timber hook to a circus tent is money well spent.

Consistency, too, is an important item. The product and the policy of this Company is consistent.

A Thought for 1924

The other day I met a man who said,
"In 1924 I'm going to forge ahead,—
I'll plan for more than I can do,—and do it,
I'll bite off more than I can chew,—and Chew
it."

No one will bring the world around to you,
One's destiny is much what one will make it,
Opportunity is fickle; woos no man,
The winner's he who steps right out to take it.

I've picked my goal, and set a mark to work to,
It's certain that my work will not seek me,
In 1924 My Goal is set for,—
JUST TWICE THE WORK I DID IN '23.

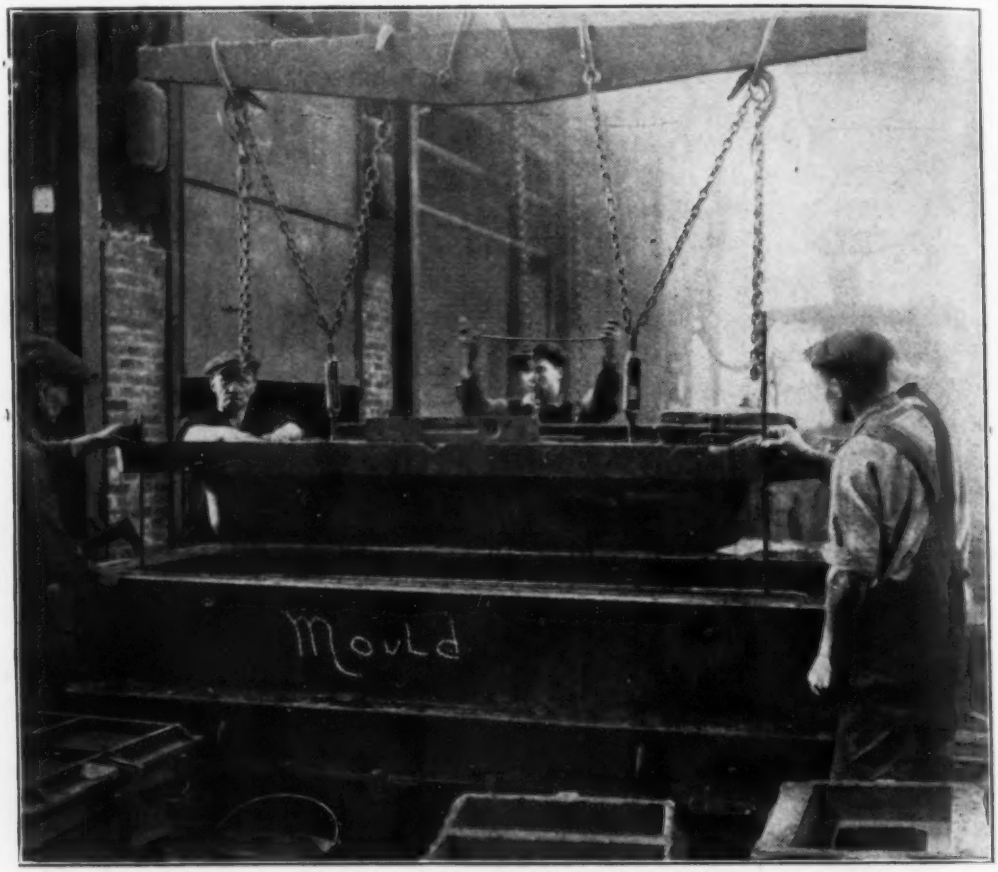
—*Krit Iklepoint.*

BOX BULLETIN SUPPLEMENT

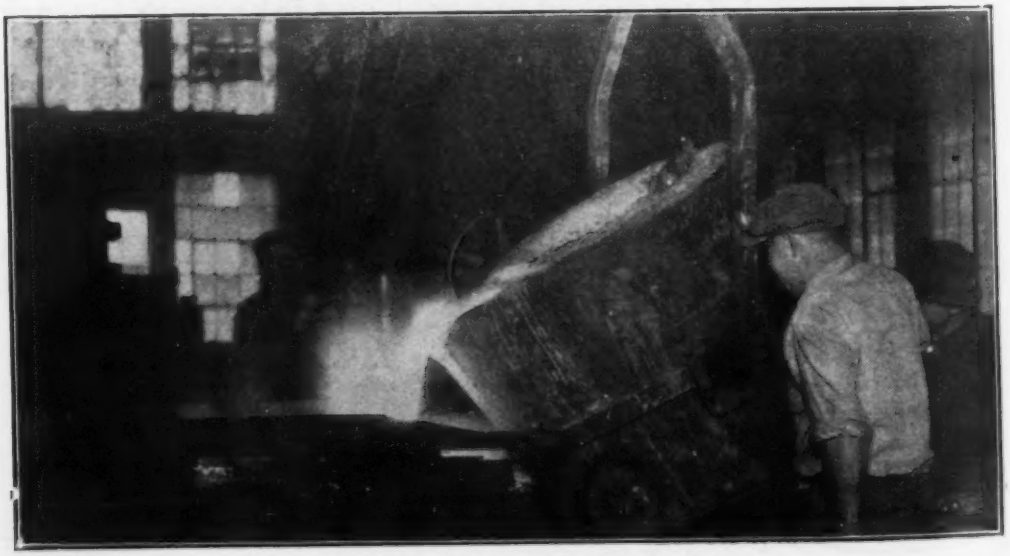
Service and Deliveries a Feature Worth Considering

We Are Taking Care of Our Customers' Requirements Promptly

All large customers have duplicate or triplicate patterns and special flask and arbor equipment which insures production of uniform castings and prompt service. This equipment is supplied by The General Alloys Company at no cost to its customers. The following pictures



Closing Mould after baking mould and core.

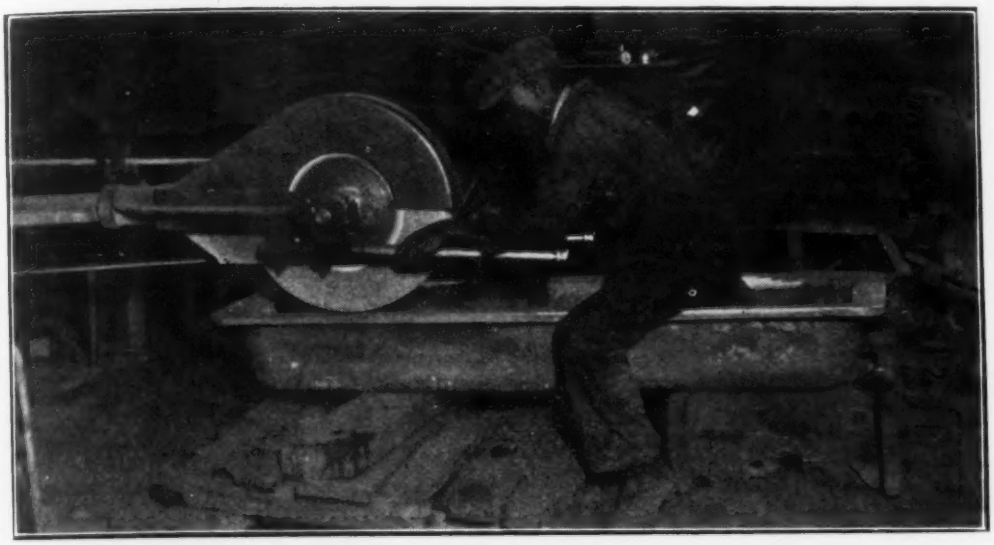


Pouring (note teakettle ladle)

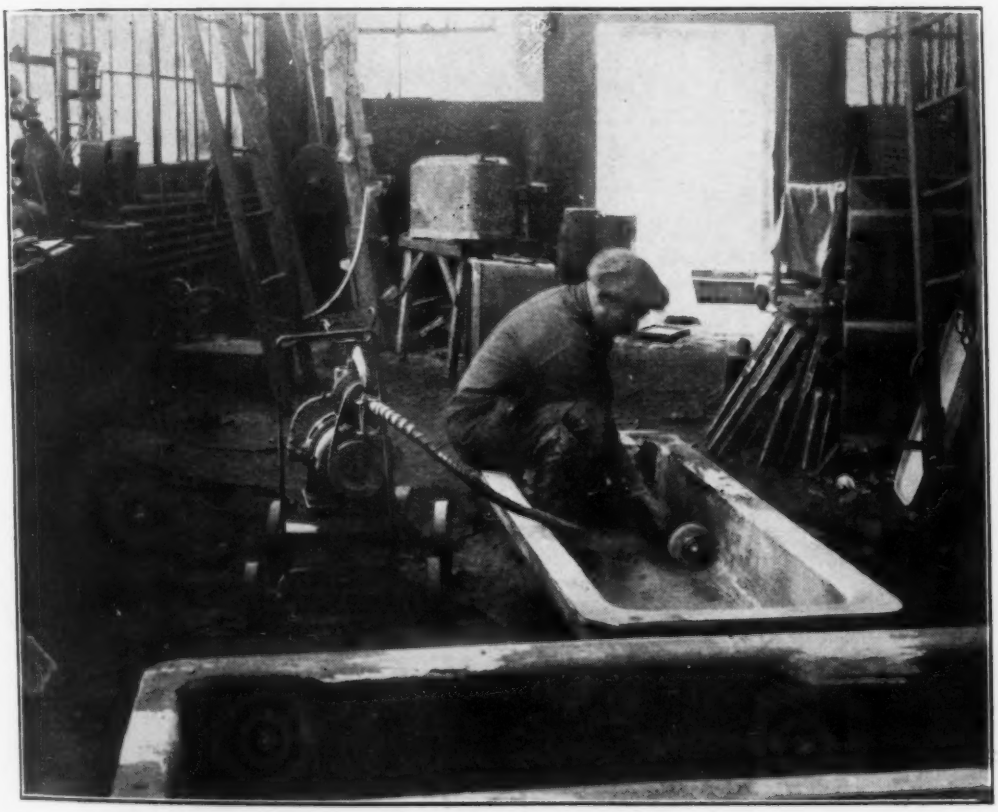
BOX BULLETIN SUPPLEMENT

show some castings and partial equipment made for Buick Motor and Dodge Brothers. Sixteen Reo Patterns, Twelve Cadillac Patterns, and Special Equipment for some of the Ford jobs will be shown in later issues of the Box Bulletin.

There was once a time that one concern had a monopoly on the Alloy Casting field. As Al Posen says, "Them Days is Gone Forever." On recent tonnage orders in Detroit district, which



Rough Grinding

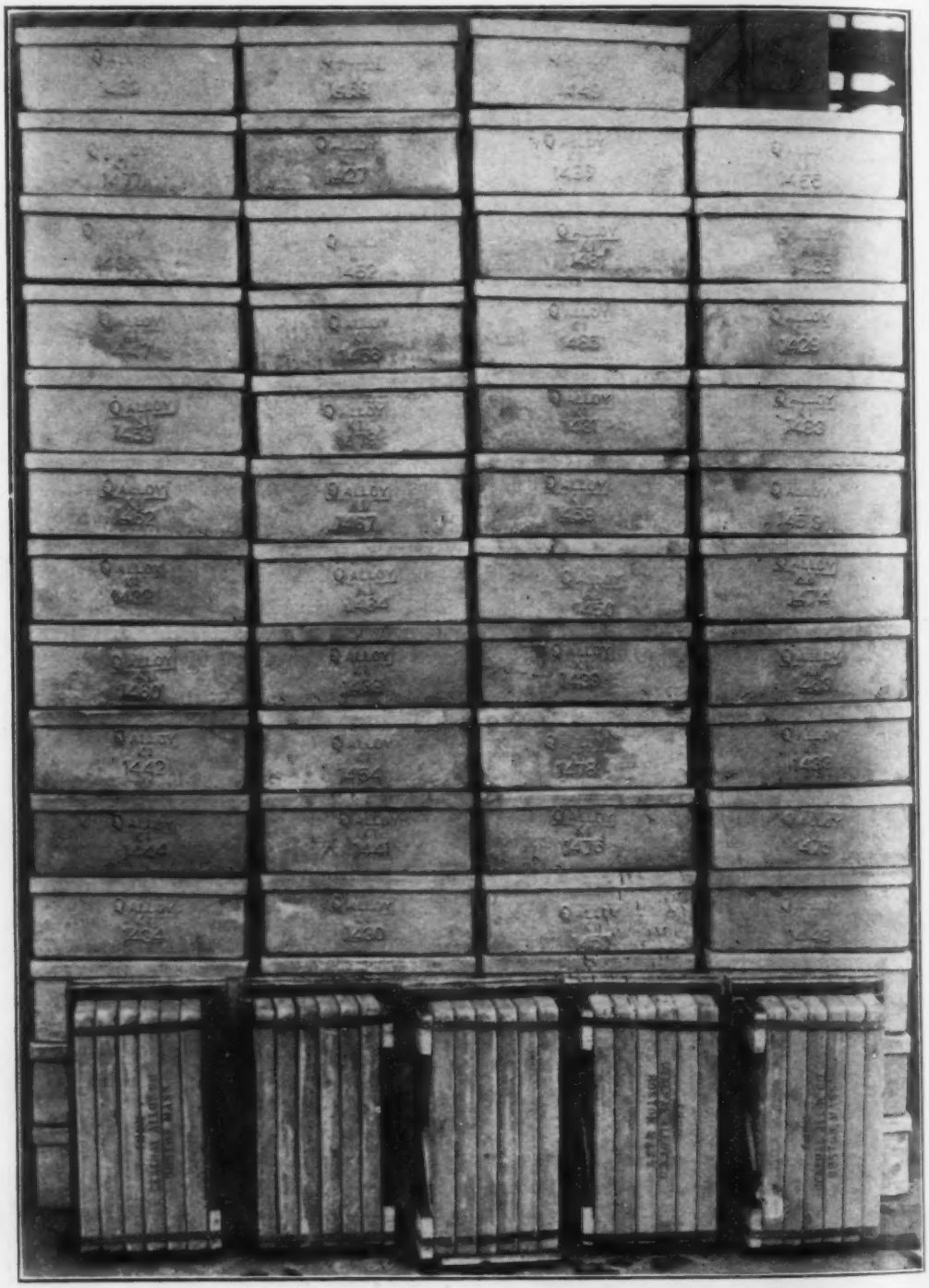


Finish Grinding

BOX BULLETIN SUPPLEMENT

were split between this company and competitors. The Q-Alloys were delivered first, 100% acceptable castings, and lighter in weight than competitive castings made from the same prints. More recent orders have not been "split." We got 'em. There has been no order placed for Heat Resisting Castings in this country during the past year too big for this Company to turn out in 30 days without interfering with our regular production schedule.

Q-Alloys are produced in electric furnaces in modern foundry equipment exclusively for their manufacture, and in which only Q-Alloy castings are produced.



Partial shipment of Dodge Bros. Orders, totalling 450 boxes.